The GLAST Technical Handbook

GLAST Science Support Center

August 23, 2007

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1 Introduction

The purpose of this document, the *GLAST Technical Handbook*, is to provide investigators with the information necessary to write proposals for the Gamma-ray Large Area Space Telescope (GLAST) Guest Investigator (GI) program, and more generally, to analyze the data produced by the GLAST mission. While a great deal of information about GLAST is provided online (http://glast.gsfc.nasa.gov/ is a good place to start), this document is meant to provide a coherent introduction to the GLAST mission.

This handbook summarizes many GLAST mission policies; however, while every attempt is made to ensure that these policies are presented accurately, this is not a policy document. The Research Opportunities in Space and Earth Sciences (ROSES), the relevant NASA Research Announcement (NRA), is the ultimate legal statement concerning the GI program. Additional information can be found on the website of the GLAST Science Support Center (GSSC): http://glast.gsfc.nasa.gov/ssc. Observatory policies are governed by the GLAST Science Policy Document and the GLAST Project Data Management Policy Document.

2 Overview

2.1 Mission Overview

GLAST is an international and multi-agency observatory class mission that will study the cosmos in the 10 keV to >300 GeV energy range. The main instrument, the Large Area Telescope (LAT), has an effective area (>8000 cm^2), angular resolution (<3.5° at 100 MeV, <0.15° at >10 GeV), field-of-view (FOV, >2 sr), and deadtime (< 100 μs) that will provide a factor of 30 or more advance in sensitivity compared to previous missions, as well the capability for studying transient phenomena. The LAT's energy range is < 20 MeV to > 300 GeV. The GLAST Burst Monitor (GBM) will have a FOV larger than the LAT and will provide spectral coverage of gamma-ray bursts extending from 30 MeV, above the LAT's lower limit, down to 8 keV. Although pointed observations will be possible, the observatory will most likely scan the sky continuously because of the LAT's large FOV; this survey mode is planned for GLAST's first year.

GLAST will be launched no earlier than January 31, 2008, into an initial orbit of ∼565 km altitude at a 25.3° inclination and an eccentricity <0.01. The launch vehicle's extra lift capacity may be used to lower the orbital inclination by a few degrees. The mission design lifetime is a minimum of 5 years, with a goal of 10 years. After a ∼60 day checkout period (Phase 0), science operations will begin. The first year of science operations (Phase 1), which will coincide with the first cycle of the GI program, will be devoted to a survey of the sky; consequently GIs will not be able to change GLAST's observing schedule. Summary LAT data and all GBM science data will be released, but LAT count data will not be released while the LAT team calibrates their instrument. During subsequent years (Phase 2) all science data will be public and GIs may request observations that differ from the default sky survey mode.

During normal operations the GLAST observatory will communicate with the ground through the Tracking and Data Relay Satellite System (TDRSS). GLAST will downlink science and housekeeping data 6–7 times a day during ∼ 10 minute contacts on the Ku band. Commands implementing the observing timeline, and maintenance of the spacecraft and the instruments, will be uploaded once a week. However, the GLAST mission can respond rapidly to astronomical transients through target-of-opportunity (TOO) observations commanded from the ground and autonomous repoints initiated by the spacecraft.

When either instrument detects a gamma-ray burst, GLAST will send summary data including localizations via TDRSS to the ground in ∼15 s. In addition, if the burst is sufficiently intense the spacecraft will repoint autonomously to place the burst location in the center of the LAT FOV for 5 hours (default, with interruptions by Earth occultations) to search for a gamma-ray afterglow.

The data will undergo a number of transformations between the detection of photons by the GLAST instruments until scientific results are published. As explained in greater detail below, at various points the data will be assigned a level number. Level 0 data will be a version of the spacecraft telemetry with repeated and corrupted data packets removed, and the packets in time order. Resulting from processing by the instrument teams, Level 1 data will be ready for astrophysical data analysis. For example, lists of counts from each instrument that can be used for spectral fitting will be Level 1 data. Level 2 data will be the products of this astrophysical analysis, and include spectral fits and source localization. Catalogs and compendia of Level 2 data will be considered Level 3 data.

2.2 Instrument Overview

A product of a collaboration between NASA, the Department of Energy (DOE) and international partners, the LAT builds on the success of the Energetic Gamma-Ray Experiment Telescope (EGRET) on the *Compton Gamma-Ray Observatory (CGRO)*. The LAT is a pair conversion telescope: gamma rays pair-produce in tungsten foils; silicon strip detectors track the resulting electron-positron pairs; the resulting particle showers deposit energy in a CsI calorimeter; and an anticoincidence detector vetoes the large flux of charged particles that are also incident on the LAT. The anticoincidence detector (which detects charged particles) is segmented to limit the self-vetoing that plagued EGRET (discussed in greater depth in §4.2). The LAT's outside dimensions are approximately 1.8 m$\times$1.8 m$\times$1m, and its mass is $\sim$3000 kg.

Astrophysical photons will be only a small fraction of all the events the LAT will detect in orbit, most of which will result from charged particles. Therefore, event filtering on board will reduce the $\sim$3 kHz detected event rate to $\sim$300 Hz that will be telemetered to the ground; ground processing will result in a $\sim$2–3 Hz photon rate.

A follow-up of *CGRO*'s Burst And Transient Source Experiment (BATSE), the GBM will detect gamma-ray bursts and extend GLAST's burst spectral sensitivity to the $<$10 keV to 30 MeV band. Consisting of 12 NaI(Tl) (8-1000 keV) and 2 BGO (0.15–30 MeV) detectors, the GBM will monitor $>$8 sr of the sky, including the LAT's FOV. Bursts will be localized to 9° (1σ, brightest 40 percent of the bursts) by comparing the rates in different detectors. The GBM will trigger if the rates in two or more detectors increase by more than 4.5σ. The trigger will use a variety of energy bands and time windows.

The primary data products from both instruments are count lists. In this document 'count' refers to an individual event that can be included in astrophysical data analysis (e.g., spectral fitting). Note that in this usage count refers to individual events, and not the number of events in an energy or time bin. The LAT's count list provides quantities such as the arrival time, energy, and origin (and their associated uncertainties) for all events identified by the LAT instrument team as photons. The GBM's count list provides the arrival time and energy (in one of 128 channels) for counts detected before and after a burst trigger.

2.3 Ground System Overview

The Mission Operations Center (MOC), housed at the NASA/Goddard Space Flight Center (GSFC), will control the GLAST observatory. All commands to, and telemetry from, the spacecraft will pass through the MOC. The instrument teams will operate Instrument Operations Centers (IOCs) called the LAT Instrument and Science Operations Center (ISOC) and the GBM IOC (GIOC). In addition to monitoring and maintaining their instruments, the IOCs will also process the output from their instruments, resulting in data ready for astrophysical analysis.

The GLAST Science Support Center (GSSC), which is part of the Office for General Investigator Programs (OGIP) at GSFC, supports the general scientific community. The GSSC will manage the GLAST GI program on behalf of NASA Headquarters. All publicly-available data products, software, calibration files and technical documents will be available through the GSSC website (see http://glast.gsfc.nasa.gov/ssc/). The GSSC will also assist the general community through an online 'help-desk' (see http://glast.gsfc.nasa.gov/ssc/help/).

3 Observatory Policy

3.1 Data Rights

3.1.1 Cycle 1 Data Policy

During the first GI cycle, corresponding to the (approximately) first year of science observing, the LAT instrument team will post the fluxes, spectra and lightcurves of at least 20 scientifically interesting gamma-ray sources and will release similar summary data for bright transients (see §3.1.3). Proposals to analyze these data products are encouraged.

The preliminary list of sources detected by the LAT that will be released by the LAT team halfway through the first GI cycle is meant for supporting proposals for the second GI cycle, and not for research purposed during the first cycle.

LAT count lists will be available only to members of the LAT instrument team during the first cycle. Therefore, analysis of LAT count data may not be part of the research program proposed for the first GI cycle.

All GBM science data will be released during this cycle, and analysis of these data may be proposed.

Both the LAT and the GBM will release catalog entries (e.g., location, duration and spectral parameters) for each burst.

The data are described in detail in §8.

3.1.2 Data Policy in the Second and Subsequent Cycles

In the second and subsequent cycles all science data from both instruments will be released as soon as they are processed.

There will be no proprietary period for LAT data for GI-proposed sources in the second and subsequent cycles. The LAT has a very large FOV, will generally scan the sky, and will slowly build up exposure on sources of interest. Restricting an entire dataset that contains a source to one investigator would be inefficient. The LAT's energy-dependent point spread function, which is broad at low energy, necessitates analyzing a $\sim 15^\circ$ region around a source of interest; restricting access to portions of the FOV would make it difficult for investigators to study nearby sources.

The LAT instrument team will continue to post the fluxes, spectra and lightcurves of a set of scientifically interesting sources and transients. Both instrument teams will continue to compile and post source and burst catalogs.

3.1.3 Transients

To facilitate correlated observations, the GLAST instrument teams will release to the community fluxes, spectra, lightcurves and locations for transient gamma-ray sources.

The LAT instrument team will release data for sources when they first exceed 2×10^{-6} photons cm^{-2} s^{-1} (>100 MeV) until they fall to a flux level of one-tenth this threshold.

Appropriate data for gamma-ray bursts will be released as soon as practical. Summary information such as position, flux, duration and spectral parameters will be calculated and posted if an instrument detects a burst, while upper limits will be provided if an instrument does not detect a burst.

3.1.4 Monitored Sources

Approximately 20 pre-selected sources will be monitored continuously by the LAT instrument team and the fluxes and spectral characteristics will be posted on a publicly accessible web site. These sources are predominantly bright blazars that were detected by EGRET or other high energy observatories. Additional scientifically interesting sources may be added to this list. This list is posted at http://glast.gsfc.nasa.gov/ssc/data/policy/LAT_Monitored_Sources.html.

3.2 The Guest Investigator (GI) Program

GLAST will have a GI program with approximately yearly 'cycles;' some cycles may be somewhat longer or shorter than a year based on schedule exigencies. The first cycle will correspond to the first year of scientific observations (Phase 1). The GLAST GI program is part of the Research Opportunities in Space and Earth Sciences (ROSES) NRA. Thus the first GLAST GI cycle was announced in the 2007 ROSES NRA. More detailed information is provided on the GSSC website. NASA uses a single, uniform set of instructions for the submission of proposals submitted in response to a NRA such as ROSES; see the NASA Guidebook for Proposers (http://www.hq.nasa.gov/office/procurement/nraguidebook/). Proposers should follow these instructions, except as otherwise stated.

Therefore, the priority for proposal instructions is: 1) ROSES; 2) the NASA Guidebook for Proposers; 3) the proposal webpage on the GSSC website (http://glast.gsfc.nasa.gov/ssc/proposals/cycle1/); and 4) this handbook. Thus if there is an apparent conflict between this handbook and the text in ROSES, the text in ROSES will be followed.

In Cycle 1 investigators cannot propose specific GLAST observations; for example, investigators cannot request pointed observations, modifications of the default survey mode, or pre-approved target-of-opportunity (TOO) observations (anyone can request that the Project Scientist approve a TOO observation on an ad hoc basis). The Cycle 1 GLAST GI program solicits proposals in the following areas:

- Analysis using any of the data released during Cycle 1, including correlative multiwavelength observations with other instruments and observatories that are directly relevant to GLAST science objectives. Because correlative observations will substantially augment

Date	Action
February 16, 2007	Cycle 1 announced in 2007 ROSES NRA
June, 2007	Proposal Materials Posted on GSSC Website
July 13, 2007	Notice of Intent due (optional)
September 7, 2007	GI Cycle 1 Proposal Deadline
December, 2007	Peer Review Panel Meets
January 31, 2008 (or later)	Launch
Launch+60 days	GI Cycle 1 Begins

Table 1: Approximate critical dates for Cycle 1 of the GLAST GI program.

the science return from GLAST, such proposals are encouraged. Examples of correlative observations that will add significantly to the GLAST science include monitoring of blazars, follow-up observations of gamma-ray burst afterglows, and determination of pulsar ephemeredes. During Cycle 1 the LAT instrument team will post the light curves (including spectral information) of ∼20 pre-selected sources (see http://glast.gsfc.nasa.gov/ssc/data/policy/LAT_Monitored_Sources.html), will announce the discovery of bright transients, and will provide light curves and locations for these sources.

- The analysis of burst data from the GBM. The GBM will provide event lists accumulated during the burst, permitting both temporal and spectral studies. In addition, background count rates with differing temporal and spectral resolution also will be available, enabling background studies and source detection through occultation steps.

- Development of data analysis techniques applicable to the data provided by the GLAST instruments that will maximize the mission's scientific yield are also encouraged. While the GLAST mission will provide a basic set of analysis tools applicable to the GLAST data, specialized techniques might address such specific scientific issues as blind pulsar period searches, the discovery of faint transients, and the detection of sources through occultation steps in the GBM background light curves. GI proposals for new data analysis techniques are solicited and should specifically address how the proposed techniques will advance GLAST science objectives. Because LAT event data will not be public until the start of Cycle 2, techniques that cannot be developed without access to such data are not solicited during Cycle 1.

- Theoretical investigations that will advance the mission science return of GLAST hold the potential to significantly enhance the scientific impact of the mission. GI proposals for such theoretical investigations should specifically address how the anticipated results will advance GLAST science objectives. (Approximately 10% of GLAST GI funding is expected to be devoted to such theoretical efforts.) Computer resources are available through the High-End Computing Program (https://www.hec.nasa.gov/; see also §10.4.3)

- GLAST-relevant observations on the facilities of the National Radio Astronomy Observatory (NRAO). The GLAST GI Program will award approximately 10% of the observing time on the Very Long Baseline Array (VLBA), the Very Large Array (VLA), and the Robert C. Byrd Green Bank Telescope (GBT), for observing programs equivalent to"regular" NRAO proposals, those requesting fewer than 200 hours of observing time. This program is described in greater depth in §3.3; the proposal process is outlined in §10.4.1.

- GLAST-relevant optical observations on the facilities available through the National Optical Astronomy Observatory (NOAO). The GLAST GI Program will award observing time on a large number of NOAO telescopes. This program is described in greater depth in §3.4; the proposal process is outlined in §10.4.2.

GIs may propose GLAST investigations that avoid duplication of two main goals of the LAT science team: (1) development of event-reconstruction and background-rejection techniques and (2) production of a catalog of gamma-ray sources. The extent to which the proposed research will enhance the science return from GLAST will be considered in the proposal evaluation process.

Scientists based at foreign institutions cannot receive NASA funding, but may submit proposals for evaluation (these evaluations can be used to support funding requests to other funding agencies). Co-investigators sited at US institutions can request funding consistent with the level of effort they will provide to a foreign-led proposal.

In subsequent cycles investigators may propose GLAST observations. In addition to pointed observations, modifications of the default survey mode, or pre-approved TOO observations, investigators may propose that GLAST remain in the default survey mode at specific times, thus precluding pointed observations at these times. Scientists sited at foreign institutions may propose research programs that affect the GLAST observing schedule after the first cycle, but they cannot receive NASA funding in support of these observations.

GLAST science team members (instrument teams, GSSC staff, IDSs, etc.) who are not fully funded by the GLAST mission can receive Cycle 1 funding for research using publicly available data. Thus LAT team members and their collaborators cannot propose a research program based on their access to LAT event data in Cycle 1.

A peer evaluation panel will review all proposals with respect to the following criteria:

- The suitability of using the GLAST observatory and data products for the proposed investigation

- The extent to which the investigation enhances the anticipated science return from the GLAST mission
- The degree to which the proposed investigation places demands upon mission resources.

It is understood that the relevance of a proposal shall include the following factors:

- The extent to which the investigation supports NASA's Strategic Goals and Outcomes (see Table 1 of the ROSES NRA)
- For data analysis development and theoretical investigations, the degree to which the investigation directly advances GLAST science goals

3.2.1 Proposal Process

GLAST will use a two phase proposal process. In the first phase proposers will submit only a scientific justification; a peer review panel will evaluate this first phase proposal. Only proposers whose proposals are accepted in the first phase will submit a second phase budget proposal. Proposers will fill out only a Research Proposal System (RPS—OGIP's web-based system) form for the first phase; the scientific justification will be a PDF file uploaded to RPS's server. Thus in the first phase proposers do not fill out a NASA Solicitation and Proposal Integrated Review and Evaluation System (NSPIRES—NASA's web-based system) form; however, they and all their US Co-Is do have to be registered with NSPIRES. Proposers will include an estimated maximum budget amount on the RPS form. They also will report the number of NASA civil servant FTEs that will be supported by the proposal if it is accepted. The form is discussed in greater detail below in §10.4.

If the proposed research plan will address the observations of specific sources either by GLAST or other observatories, these sources must be reported on the RPS target form. Proposers may either fill in the form for each source individually, or upload a file with a list of targets.

Proposers whose first phase proposals are tentatively accepted will then submit a budget in the second phase through NSPIRES; basic information about the accepted proposals (PI name, institution, proposal name, etc.) will already be in the NSPIRES system.

In Cycle 1 there will be two proposal classes: (1) Regular proposals with research plans that can be completed in one year and (2) Large proposals whose research plans are more expansive and may take up to three years to complete. The number of Large projects funded, and corresponding budgets awarded in any given year, will be limited. Large projects will be reviewed each year to determine if appropriate progress is being made toward the proposed objectives. Because of the significant resources that are allocated to Large projects, those that do not make progress consistent with the proposed investigation may be reduced or terminated. In order to permit annual evaluation, PIs of approved

Large projects must submit a progress report annually on the Phase 1 proposal due date rather than on the anniversary of the award date. The scientific justification for Regular proposals has a 4 page limit, while Large proposals have a 6 page limit.

3.2.2 Fellows Program

The NASA-sponsored GLAST Fellowship Program will provide an opportunity for highly qualified postdoctoral scientists to conduct independent research that is broadly related to the goals of the GLAST mission.

The Fellowship will provide support for up to three years, with some allowance for travel and other research costs.

Further information about the Fellows Program will be provided in the future.

3.3 The NRAO Cooperative Agreement

In recognition of the importance of radio observations using the NRAO facilities to the scientific exploration by GLAST, this GLAST-NRAO cooperative arrangement commits observing time on NRAO telescopes towards coordinated observations of GLAST, on a competitive basis. The scientific programs that will be supported within this program are those that are enhanced by the combination of GLAST observations with investigations using the radio facilities operated by NRAO. The philosophy of the approach, in keeping with the missions of both GLAST and NRAO, will be that of maximum data availability and maximum scientific return for the entire user community.

This cooperative arrangement includes two distinct types of collaborative observations and funding opportunities between NRAO and GLAST that will take place within the GI program. To distinguish these two opportunities, we call them the "Joint Proposal Opportunity" and the "Cooperative Proposal Opportunity," respectively. The two opportunities are described in turn below.

3.3.1 Background Description of NRAO Radio Telescopes

The NRAO operates the Very Long Baseline Array (VLBA), a milliarcsecond-resolution continent-wide interferometer array; the Very Large Array (VLA), to be "replaced" by the Expanded VLA (EVLA) in 2010, an arcsecond-resolution centimeter-wave interferometer array; and the Robert C. Byrd Green Bank Telescope (GBT), a precise 100m single-aperture telescope. In addition, the NRAO is the North American Executive of the Atacama Large Millimeter/Submillimeter Array (ALMA), to be completed in 2012, with first science using about 15 telescopes in 2010. The present agreement covers the GBT, VLA, and VLBA, with the potential of adding ALMA and EVLA as they come on line. The total amount of scientific observing time used on the operational NRAO telescopes ranges from 4500 to 6500 hours per year. The GBT, VLA, and VLBA are pointed telescopes generally allocated for PI proposals; their data proprietary period is 12 months, beginning at the time of the last observation associated with a proposal. NRAO also accepts "Large Proposals" requesting at least 200 hours of NRAO observing time at intervals of 8–12 months. NRAO is funded by NSF as a research facility that operates state-of-the-art telescopes in an "open skies" mode for the entire astronomical community.

3.3.2 Joint Proposal Opportunity

The first GLAST/NRAO opportunity is a Joint Proposal Opportunity, whereby potential radio observers submit proposals for GLAST funding and future NRAO observations through the GLAST GI portal. A range of telescope time will be made available by NRAO for the GLAST GI program. In turn, GLAST/NASA will make data-analysis funding available to successful U.S.-based investigators requesting NRAO observing time through the GI process. In GLAST Cycle 1, these proposals will make use of GLAST survey data products, while those for succeeding cycles may also include both NRAO and GLAST pointed observations. The peer-reviewed GI proposal-evaluation process will identify programs with sufficient science justification to be allocated funding by GLAST, and those that fall within the agreed-on range of NRAO observing time will be allocated NRAO observing time without additional scientific review.

Proposals for NRAO observing time submitted through the GLAST GI program will be successful only if they make use of the unique capabilities of the NRAO telescopes; proposal evaluation will include an assessment of the radio telescope requirements, and those that are more appropriately done with other radio telescopes will be rejected. Only proposals equivalent to "regular" NRAO proposals, those requesting fewer than 200 hours of observing time, will be eligible to be submitted for future observing time. NRAO Large Proposals (200 hours or more) will not be eligible because of their potential large impact on the available funding and observing time, but will be eligible for funding via the Cooperative Proposal mechanism (see below). Some examples of NRAO observations that would be acceptable might include, but are not limited to, the following:

- High-resolution rapid source surveys for spectral-energy distributions and candidate identification
- High-resolution imaging to follow morphological evolution of flaring sources
- Timing of weak millisecond pulsars to enable folding of the gamma-ray light curves with respect to the pulsar period
- Multi-frequency spectral monitoring of radio-weak, flaring gamma-ray sources

The radio data will be the property of the proposers for the standard NRAO 12-month proprietary period.

The actual amount of NRAO observing time allocated via the Joint GLAST Process will depend on the amount of proposal pressure and the scientific quality of the proposals. We anticipate that a maximum of 10% of the NRAO scientific observing time would be made available on GBT, VLA, and VLBA, or up to 450–650 hours per year on each telescope. If there are very strong scientific proposals for more time, and the GLAST mission has funds available to support data analysis, the GLAST Project Scientist will request additional time from the NRAO Director, who will set up an NRAO mechanism to evaluate and respond to this request.

Accepted regular NRAO proposals may include observations that have some overlap with observations approved in the GLAST GI Cycle. NRAO and the GLAST mission will resolve such duplications on a case-by-case basis; the default resolution will be that a single observation will be made and the data shared among the respective teams.

3.3.3 Cooperative Proposal Opportunity

Direct proposals for NRAO observing time that will enhance the scientific return associated with the GLAST mission also may be eligible for NASA funding through the GI program. These proposals will be of two NRAO types-Large Proposals (requesting 200 or more hours of NRAO observing time) and target-of-opportunity (TOO) proposals, which respond to time-critical transient events. NRAO typically accepts and evaluates Large Proposals annually, whereas TOO proposals are accepted at any time. These are distinguished from the proposals in §3.3.2 because they would involve requests for GLAST GI funding that are made subsequent to NRAO approval of observing time. Proposers of NRAO observations who also intend to propose for GLAST funding via this route must indicate their intentions clearly in the NRAO proposal, and all information related to the NRAO review of successful proposals will be forwarded to the GLAST mission for their evaluation. Note that the award of NRAO observing time will not be a guarantee of GLAST funding; likewise the observing time is not contingent on GLAST funding in this case.

See http://www.nrao.edu/administration/directors_office/largeprop.shtml and http://www.vla.nrao.edu/astro/proposals/rapid for further descriptions of the NRAO Large and Target-of-Opportunity proposals.

3.3.4 Credits and Attributions

For results obtained using GLAST and NRAO facilities, proper attribution to NRAO facilities must be included in all publications, conference proceedings, posters, abstracts and talks and colloquia, as in the following: "The National Radio Astronomy Observatory is a facility of the National Science Foundation operated under cooperative agreement by Associated Universities, Inc." GLAST attribution will be the same as for all other use of GLAST data products.

3.4 GLAST-NOAO Cooperative Arrangement

In recognition of the importance of optical observations enabled by the National Optical Astronomy Observatory (NOAO) to the scientific exploration by the Gamma-ray Large Area Space Telescope (GLAST), the GLAST-NOAO cooperative arrangement commits observing time on NOAO telescopes for coordinated observations of GLAST-relevant sources, on a competitive peer-reviewed basis. The scientific investigations that will be supported within this program are those that are enhanced by the combination of GLAST observations with investigations using the optical facilities operated by NOAO and/or those nominally accessed via the NOAO Time Allocation Committee process. Some examples are given below. The philosophy of the approach, in keeping with the missions of both GLAST and NOAO, will be that of maximum data availability and maximum scientific return for the entire user community. This agreement is similar in scope and intent to existing agreements between GLAST and other organizations (e.g., NRAO) and between NOAO and other observatories (e.g. the Hubble Space Telescope, the Spitzer Space Telescope, and the Chandra X-ray Observatory). Here we describe this agreement as it applies to GLAST's Cycle 1 only.

The collaborative proposal process will be implemented via the normal GLAST GI Program. Note that regular proposals to NOAO are evaluated every six months (proposal deadlines the end of March and September), whereas the GLAST GI Cycle will be annual. There are two distinct types of collaborative observations and funding opportunities between NOAO and GLAST that will be implemented through the GLAST GI program. To distinguish these two opportunities, we call them the "Joint Proposal Opportunity" and the "Cooperative Proposal Opportunity," respectively. The two opportunities are described in turn below.

3.4.1 Background Description of NOAO Telescopes

NOAO's mission is to provide to the community merit-based access to state-of-the-art optical and near IR observational capabilities over a full range of telescope apertures for the purposes of carrying out forefront research and educational activities. NOAO is operated by Associated Universities for Research in Astronomy, Inc., under a cooperative agreement with the National Science Foundation. NOAO operates Kitt Peak National Observatory (KPNO) near Tucson, Arizona, on land leased from the Tohono O'odham Nation, and Cerro Tololo Inter-American Observatory (CTIO) near La Serena, Chile. The NOAO Gemini Science Center, part of NOAO, provides researchers access to the two 8-m telescopes of the Gemini Observatory, located in Hawaii and Chile. NOAO also provides limited access to other leading ground based observatories via the NOAO Time Allocation Committee (TAC) process. These facilities include the W. M. Keck Observatory, the Hobby-Eberly Telescope (HET), the MMT (6.5-m telescope), and the Magellan (twin 6.5-m telescopes).

3.4.2 Joint Proposal Opportunity

The first GLAST/NOAO opportunity is a Joint Proposal Opportunity, whereby potential optical, near-IR, and mid-IR observers submit proposals for GLAST funding and future NOAO observations through the GLAST GI portal. The implementation plan for this opportunity will be described in a separate document, which may be modified by mutual GLAST/NOAO agreement without renegotiating this program. A range of telescope time (see below) will be made available by NOAO for the GLAST GI program. It is anticipated that the list of available facilities will be revised prior to each GLAST call for proposals. Changes will be made as required to respond to changes in the availability of telescopes/instruments and on-going evaluation of the utility of various capabilities to contribute significantly to the science mission of GLAST. In turn, GLAST/NASA will make data-analysis funding available to successful U.S.-based investigators requesting NOAO observing time through the GI process. In GLAST Cycle 1, these proposals will make use of GLAST survey data products, while those for succeeding cycles may also include both NOAO and GLAST pointed observations. The peer-reviewed GI proposal-evaluation process will identify programs with sufficient science justification to be allocated funding by GLAST, and those that fall within the agreed-on range of available NOAO observing time and pass the nominal NOAO technical review (feasibility and schedulability) will be allocated NOAO observing time and GLAST funding without additional scientific review.

Proposals for NOAO observing time submitted through the GLAST GI program will be successful only if the proposed ground based observations are necessary for the realization or significant enhancement of the proposed science program. Examples of science topics that will directly benefit from joint observations include:

- Long-term photometric monitoring on selected GLAST objects to understand optical variability in the gamma-ray quiescent state.
- Counterpart candidate studies, including redshift determination of previously unknown BL Lacs and high-redshift blazars.

This list is intended to illustrate the kinds of opportunities enabled joint program and it is not exclusive. Proposals for other GLAST-NOAO investigations are also welcome.

For Cycle 1 only the following telescopes and associated instruments are available for time allocations at the stated levels of observing time via proposals to the GLAST request for proposals. [Note that Target-of-Opportunity (TOO) Proposals cannot be submitted via this process, but can be submitted via the "Cooperative Proposal Opportunity" described in following section]

- CTIO Blanco 4-m telescope (5%; approximately 15-18 nights a year)
- SOAR 4.2-m telescope (1.5%; this is 5% of the 30% share of time NOAO has on this telescope)

- KPNO Mayall 4-m telescope (5%; approximately 15-18 nights a year)
- WIYN 3.5-m telescope (2.0%; this is 5% of the 40% share of time NOAO has on this telescope)
- KPNO 2.1-m telescope (5%, with perhaps up to 15% depending on the collective proposal pressure for this telescope; approximately 15-50 nights a year)
- WIYN 0.9-m telescope (up to 5%, approximately 15-18 nights a year; via NOAO time on this telescope; note that this will generally not include the use of the MOSAIC-1 imager with this telescope, as very little time is available for NOAO users on the WIYN 0.9m using this instrument, and requests for MOSAIC-1 on WIYN 0.9m via the GLAST GI program will be scheduled on a best effort basis)
- Gemini-North and Gemini-South (5% of NOAO time, which is approximately 40 to 45% of the nights, exact number depending on engineering and commissioning schedule; note that recommended programs will have to submit the NOAO proposal form to aid the NOAO TAC assign GLAST-recommended observations to priority bands in the Gemini queue program).
- HET (up to 5% of available NOAO time on this telescope; the amount varies but is generally only a few nights a year)
- SMARTS (5% of NOAO time, or 60 hours/year, and <1 hour on any one night, on each of the four telescopes. See http://www.ctio.noao.edu/telescopes/smarts.html)

NOAO will be working to add additional access to some smaller telescopes by Cycle 2.

Because the exact number of nights available for scheduling on a given telescope varies each semester (due to variable needs for engineering/maintenance of the facilities), the exact number of available nights will not be known at the time proposals are submitted. Time reserved for proposals submitted under the process set up by the GLAST-NOAO arrangement will be expressed as percentages of the scheduled science observing time available for a given telescope. The numbers of nights listed above are representative of the numbers of nights available for the past few years and are a guide to the anticipated total number of nights available in the future. The various telescopes/facilities are currently scheduled predominantly in what is called "classical mode," i.e. proposers are assigned specific nights (or fractions of nights), although some queue or service observing telescopes are in the system of telescopes that might become available to GLAST proposals during the lifetime of this arrangement. For the purpose of proposals, we shall consider each night of telescope time as consisting of 9 hours of possible observations, while the exact amount of time available is a function of many variables. Available time will be distributed over RA range and sky brightness conditions (dark and bright time). Time requests via the GLAST GI proposal process may specify hours instead of nights, but NOAO generally schedules observing time in full night increments.

The proprietary nature of the optical data will follow the standard NOAO policies. Investigators using facilities accessed via NOAO nominally have an 18-month proprietary period. All users of data obtained from NOAO or other NSF funded facilities should use the appropriate acknowledgement (see the section below, and the NOAO web pages for updates of this wording).

The actual amount of NOAO observing time allocated via the Joint GLAST Process will depend on the amount of proposal pressure and the scientific quality of the proposals. If there are very strong scientific proposals for more time, and the GLAST mission has funds available to support data analysis, the GLAST Project Scientist will request additional time from the NOAO Director, who will set up an NOAO mechanism to evaluate and respond to this request. This might enable additional programs to be supported in such an over-subscribed cycle, but more probably will lead to an adjustment in possible time allocations for future cycles.

We recognize the possibility that accepted regular NOAO proposals may include observations that have some overlap with observations approved in the GLAST GI cycle. NOAO and the GLAST mission will resolve such duplications on a case-by-case basis in an effort to avoid excessive duplication, but scheduling multiple teams for similar/identical observing programs is not excluded.

3.4.3 Cooperative Proposal Opportunity

Direct proposals for NOAO observing time that will enhance the scientific return associated with the GLAST mission may also be eligible for NASA funding through the GI program. These proposals will be of two NOAO types: Survey Program proposals (requesting large amounts of telescope time, see the NOAO survey pages for description: http://www.noao.edu/gateway/surveys) and TOO proposals, which respond to time-critical transient events. NOAO typically accepts and evaluates Survey Program proposals once a year. TOO proposals are accepted during the regular NOAO proposal calls (these are anticipatory in nature, outlining the science that would be done with observations that would be requested when certain conditions or triggering event takes place) or in exceptional cases at any time. These two types of proposals are distinguished from the proposals in 'Joint Proposal Opportunity' (described above) because they will involve requests for GLAST GI funding subsequent to NOAO approval of observing time. Proposers of NOAO observations who also intend to propose for GLAST funding via this process must indicate their intentions clearly in the NOAO proposal, and all information related to the NOAO review of successful proposals will be forwarded to the GLAST mission for their evaluation. Note that the award of observing time will not be a guarantee of GLAST funding. Likewise, the observing time is not contingent on GLAST funding in this case.

See http://www.noao.edu/gateway/surveys and http://www.noao.edu/noaoprop/help/too.html for further descriptions of the NOAO Survey and TOO proposals.

3.4.4 Scheduling of NOAO Observing Time and Award of Research Funding by NASA

The recommendations for observing time made as a result of the proposal processes outlined above will be scheduled on a best effort basis by the observatories. In general the majority of recommended programs will be scheduled, but practical constraints (availability of instruments, etc.) might occasionally prevent the scheduling of an otherwise meritorious and well ranked proposal. Further, if weather prevents a program for obtaining data, NOAO does not generally reschedule such programs unless the program is again recommended by a TAC. Similarly, most technical problems will not result in a program being given additional observing time. Programs that suffer from major failures (e.g., loss of an entire observing run due to technical difficulties) are sometimes rescheduled. Such decisions are made on a case-by-case basis by the respective observatory director.

In a similar manner, a program recommended for funding by NASA as a result of one of the two proposal processes outlined above is not guaranteed to receive funding. Such decisions follow the guidelines outlined by NASA and the GLAST mission.

3.4.5 Credits and Attributions

For results obtained using GLAST and NOAO facilities, proper attribution to NOAO facilities must be included in all publications, conference proceedings, posters, abstracts and talks and colloquia, as in the following: "This work is based [in part] on data obtained using the (appropriate telescopes) at (appropriate facility) of NOAO, which is operated by AURA, Inc., under a cooperative agreement with the National Science Foundation." Proper attributions to NOAO facilities must also be included in all NASA press releases and press conferences. GLAST attribution will be the same as for all other use of GLAST data products.

3.5 Mission Governance

The Project Scientist is responsible for operating the GLAST observatory consistent with the mission's policies. For example, the Project Scientist or his/her designee will approve or reject requests for TOO observations. The Program Scientist is the NASA HQ scientist responsible for the GLAST mission. The GLAST Users' Group (GUG, formerly the GLAST User's Committee—see http://glast.gsfc.nasa.gov/ssc/resources/gug/) advises the GLAST Project Scientist and the Program Scientist on policies that will affect the user community, and as such is the community's voice in operating the mission.

The policies governing the operation of the GLAST mission and its GI program are presented in the Science Policy Document, available at http://glast.gsfc.nasa.gov/ssc/resources/library/governance/SPD_v12.pdf.

4 The Large Area Telescope (LAT)

4.1 Experimental Objectives

The LAT is designed for observing celestial sources in the $<$20 MeV to $>$300 GeV energy band. The scientific objectives are:

1. Identify and study nature's high-energy particle accelerators through observations of active galactic nuclei, pulsars, stellar-mass black holes, supernova remnants, gamma-ray bursts, Solar and stellar flares, and the diffuse galactic and extragalactic high-energy radiation.

2. Use these sources to probe important physical parameters of the Galaxy and the Universe that are not readily measured with other observatories, such as the intensity of the optical-UV extragalactic background light, magnetic fields strengths in cosmic particle accelerators, and diffuse gamma-ray fluxes from the Milky Way and nearby galaxies, and the diffuse extragalactic gamma-ray background radiation.

3. Use high-energy gamma rays to search for a variety of fundamentally new phenomena, such as particle dark matter, quantum gravity, and evaporating black holes.

The GLAST LAT Collaboration includes scientists from Stanford University, including the Stanford Linear Accelerator Center (SLAC); Goddard Space Flight Center; University of California at Santa Cruz; Naval Research Laboratory; University of Washington; Sonoma State University; Texas A&M University-Kingsville; Stockholm University and Royal Institute of Technology, Stockholm; Commissariat a l'Energie Atomique, Departement d'Astrophysique, Saclay, France; Institut National de Physique Nuclearie et de Physique des Particules, France; Instituto Nazionale di Fisica Nucleare, Italy; Agenzia Spaziale Italiana, Italy; Instituto di Fisica Cosmica, CNR; Hiroshima University; Institute of Space and Astronautical Science, Tokyo; Riken; and the Tokyo Institute of Technology. In addition, Affiliated Scientists are from 29 institutions worldwide. The collaboration PI is Professor P. Michelson (Stanford).

4.2 LAT Instrumentation

The LAT detects a gamma ray by tracking the electron-positron pair that results from the photon's interaction with matter in the LAT. Because the charged particle flux impinging on the LAT is much larger than the astrophysical photon flux, the LAT is constructed to identify and reject almost all the background.

The LAT consists of an array of 16 towers surround by a segmented anticoincidence detector (ACD). Each tower includes a tracker module (TKR) and a calorimeter module (CAL) which are mounted to the instrument grid structure.

The LAT coordinate system is defined with the z axis along the LAT normal, and the y axis parallel to the axis of the solar panels.

Quantity	Capability
Energy Range	<20 MeV to >300 GeV
Energy Resolution	<10% on axis, 100 MeV–10 GeV
Effective Area	>8,000 cm^2 maximum effective area on axis
Single Photon Angular Resolution	$< 0.15°$, for $E > 10$ GeV
on-axis, 68% containment radius	$< 3.5°$, for $E = 100$ MeV
Field-of-View	>2 sr
Source Location Determination	<0.5 arcmin for high-latitude source
5σ Point Source Sensitivity, 1 year	$< 6 \times 10^{-9}$ ph cm^{-2} s^{-1} for $E > 100$ MeV
Time Accuracy	<10 μs, relative to spacecraft time
Background Rejection (after analysis)	<10% high latitude diffuse
Dead Time	<100 μs per event

Table 2: LAT instrumental capabilities.

Each TKR module consists of 18 XY tracker planes. Each XY plane has an array of silicon-strip tracking detectors (SSDs) for charged particle detection. The first 12 planes have 0.035 radiation length[1] thick tungsten plates in front of the SSDs, the next 4 planes have 0.18 radiation length thick tungsten plates, and the last 2 planes, immediately in front of the CAL, do not have tungsten plates. The SSDs in each plane actually consist of two planes of silicon strips, one with the strips running in the x direction and the other in the y direction, thereby localizing the passage of a charged particle. Gamma rays incident from within the LAT's FOV convert into an electron-positron pair in one of the TKR's tungsten plates; gamma rays can also pair-produce in the silicon strips or in other material within the LAT. The initial directions of the electron and positron are determined from their tracks recorded by the SSD planes following the conversion point. Cosmic rays also interact within the TKR modules.

Each CAL module consists of 8 planes of 12 CsI(Tl) crystal logs each. The logs are read out by PIN photodiodes at both ends. The CAL's segmentation and read-out provide precise three-dimensional localization of the particle shower in the CAL. At normal incidence the CAL's depth is 8.5 radiation lengths.

Raw detection information will be passed to reconstruction algorithms, and the products of these algorithms will be used to classify the events and determine quantities, such as event direction and energy, analyzed by the science tools.

The ACD is composed of plastic scintillator tiles read out by waveshifting fibers, supplemented with scintillating fiber ribbons, all connected to phototubes (PMTs). High energy gamma rays create a shower in the calorimeter. In EGRET, some of the X-rays in this 'backsplash' hit the monolithic anticoincidence shield, Compton-scattering off the plastic scintillator and triggering

[1]A radiation length is defined as the length in a specific material in which an energetic electron will lose 1-e^{-1} of its energy by bremsstrahlung. A gamma ray's mean-free-path for pair production is proportional to the radiation length.

the anticoincidence system. Since the gain of the shield's PMTs had to be high enough to detect particles throughout the shield, EGRET's shield was particularly sensitive to X-rays near the calorimeter (the PMTs were situated near the calorimeter). Because GLAST's ACD is segmented, it can distinguish backsplash, because a backsplash-hit tile will generally not be in the area through which the gamma ray arrived. In addition, the ACD threshold can be operated at a higher level than EGRET's, also reducing backsplash vetoes.

The LAT's Data Acquisition System (DAQ) performs preliminary cuts on events within the LAT to reduce the rate of background events that will be telemetered to the ground. The DAQ processes the captured event data into a data stream with an average bit rate of 1.2 Mbps for the LAT. The DAQ will also perform: command, control, and instrument monitoring; housekeeping; and power switching.

4.3 Data Acquisition

The astrophysical photons of primary interest will be a tiny fraction of the particles that will penetrate into the LAT's TKR. The LAT will perform onboard analysis cuts that will reduce the ∼3 kHz of events that trigger the TKR to ∼300 Hz of events that will be sent to the ground for further analysis; of these ∼300 Hz only a few Hz will be astrophysical photons. The data for an event that passes the on-board analysis cuts will be stored in a packet that is transferred to the spacecraft's solid state recorder (SSR) for subsequent transmission to the ground.

The LAT flight software includes an onboard gamma-ray burst trigger that searches for a statistically significant increase in the number of LAT events from any region of the sky. If the LAT detects a burst, it will downlink information about the detection. Because of the LAT's spatial resolution, it is likely to provide better localizations than the GBM.

4.4 LAT Sensitivity

The following subsections reproduce the LAT performance webpage, which can be found at http://www-glast.slac.stanford.edu/software/IS/glast_lat_performance.htm. The posted webpage is the LAT instrument team's authoritative statement of their instrument's performance.

4.4.1 Overview

The LAT's performance is governed primarily by three things:

- LAT hardware design
- Event reconstruction algorithms
- Background selections and event quality selections

Thus, although the hardware integration and testing are now complete, as the event selection algorithms are optimized the performance must be updated. In other words, there is not a single, intrinsic, set of science performance parameters, but rather results of choices. These are based on detailed Monte Carlo simulations, along with beam tests and ground-level muon tests to check the characterization in the simulation. Standard sets of analysis choices, and their resulting performance characteristics, will be maintained by the LAT team.

Note that a number of significant improvements are underway, particularly in the background rejection analysis. The performance summarized below is the result of studies for the LAT Service Challenge in 2007, in preparation for flight data analysis.

A result of the analysis is the production of full instrument response functions (IRFs), describing the performance as a function of photon energy, incidence angle, conversion point within the instrument, and other important parameters. The plots below represent the work of many people on the LAT team. A few important caveats:

- The background rejection analysis is done in bands of energy, resulting in the wiggles. These are under study.
- Starting from the front of the instrument, the LAT tracker (TKR) has 12 layers of 3% r.l. tungsten converters (THIN or FRONT section), followed by 4 layers of 18% r.l. tungsten converters (THICK or BACK section). These sections have intrinsically different PSF due to multiple scattering, and the performance plots are presented for both of these sections.

4.4.2 LAT Performance Plots

4.4.3 Point Source Sensitivity Plots

Using the above instrument performance characterization, we have produced additional plots related to point source sensitivity.

The first is a single-energy-bin sensitivity plot, showing the 5σ sensitivity to a high-latitude source whose spectrum is integrated over 1/4 decade in energy centered on the energy shown on the horizontal axis. Sensitivity is defined as the flux such that the log of the expected likelihood ratio for detection is 25/2 (or 5σ in the Gaussian case) and at least 5 photons. Thus, Figure 5 shows the point source sensitivity using *only* the photons in each energy bin separately. The assumptions are:

- One calendar year all-sky survey (including effects of the SAA and deadtime)
- Diffuse background flux 1.5×10^{-5} cm^{-2} s^{-1} sr^{-1} (E >100 MeV), spectral index -2.1.

The point source sensitivity using the information in all energy bins is much better than the individual energy bin sensitivities in Figure 5. We therefore

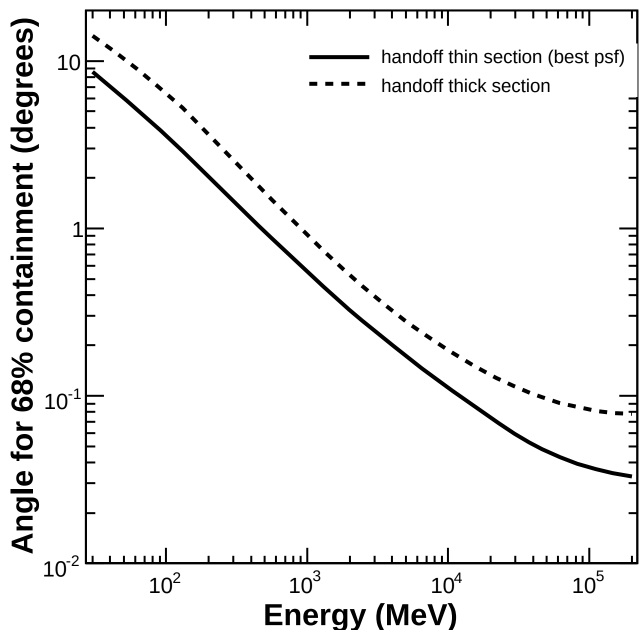

Figure 1: 68% containment of the PSF as a function of photon energy for the THIN (solid curve) and THICK (dashed curve).

provide the integral sensitivity measures in two ways. First, the bowtie plot (Figure 6), which shows the minimum needed for a 20% determination of the flux after a one-day, one-month, and one-year of operation in all-sky survey for a E^{-2} source. The resulting significance at each of these levels is about 8σ, the spectral index is determined to about 6%, and the bowtie shape indicates the energy range that contributes the most to the sensitivity. To make a measurement at that level or better, a flat spectral energy density curve must lie above the axis of the bowtie.

Finally, experiments are often compared using an integral sensitivity plot (5σ sensitivity for $E > E_0$), assuming a E^{-2} spectrum source at high latitude. In Figure 7 we show an update for the GLAST LAT.

4.5 Gamma-Ray Burst Sensitivity

Because the LAT provides temporal, spatial and spectral information for all detected counts, the burst detection algorithms applied to the data stream both onboard and on the ground search for evidence of a transient point source (i.e., a temporal and spatial count excess). Since the LAT flight software does not identify and remove all the events that did not result from photons, the onboard

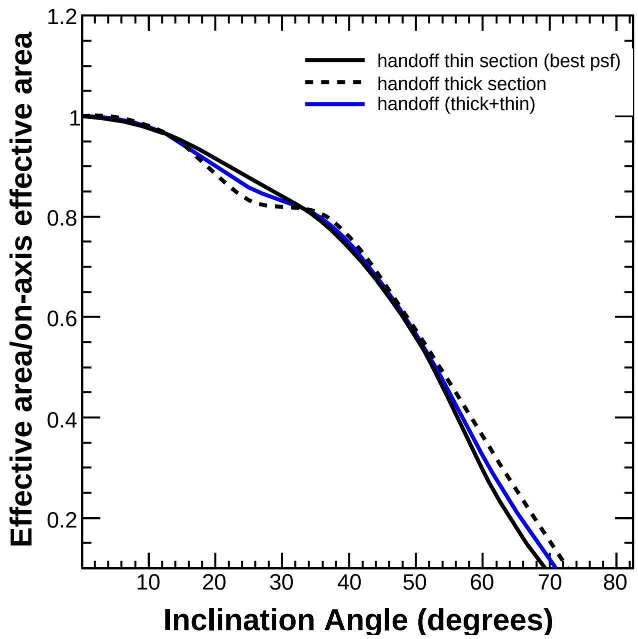

Figure 2: Relative effective area vs. photon true angle of incidence for 10 GeV photons for the THIN section(solid black curve), THICK section (dotted curve) and total (solid blue curve). The FOV is defined as the integral of effective area over solid angle divided by on-axis effective area. The inflection at 25° is an artifact of the parameterization.

burst trigger must contend with a much larger non-burst background (currently estimated to be $\sim$ 200 Hz over the LAT FOV) than the analysis on the ground (currently estimated to be $\sim$ 2 Hz over the LAT FOV). Therefore the ground trigger will be more sensitive than the trigger applied onboard, but a burst may be detected and localized within seconds onboard, while on the ground it may not be detected for many hours, long after the afterglow has faded. Note that the burst threshold varies over the LAT FOV because of the dependence of the effective area on the inclination angle.

Estimating the burst detection rate is difficult because burst phenomenology in the $\sim$1 GeV band is largely unknown. Based on the handful of bursts that EGRET detected, additional spectral and temporal components are expected in addition to the component observed in the 10–1000 keV band.

Nonetheless, estimates of the LAT detection rate have been made based on the BATSE burst rate and spectra. These estimates are conservative in that they do not include additional spectral and temporal components, but perhaps may be overly optimistic in that they do not include sub-GeV spectral breaks.

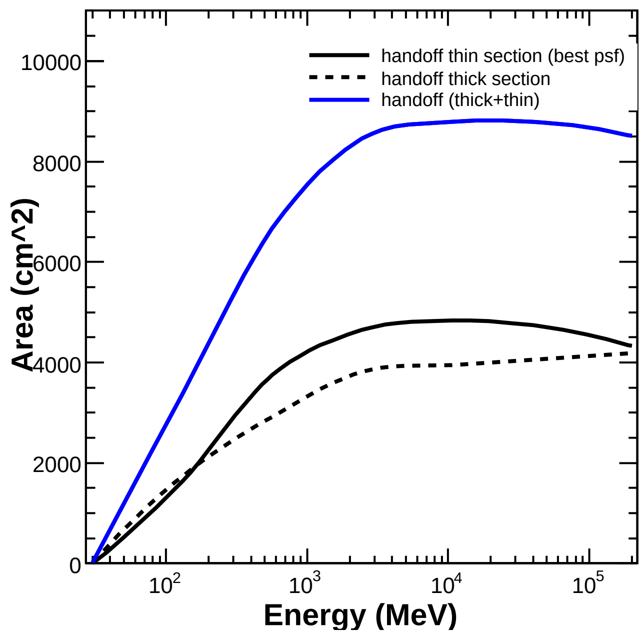

Figure 3: On-axis effective area, after all selections for the THIN section(solid black curve), THICK section (dotted curve) and total (solid blue curve).

These estimates conclude that about one burst a year will be detected with more than 1000 counts, and a burst a month with more than 100 counts.

Simulations show that burst localization improves as the count number increases, as expected. The localization also depends on the burst spectrum. For the same number of LAT counts a harder spectrum provides a better localization because the photon energies are greater and the PSFs are smaller. For an E^{-2} spectrum simulations show $\sim$3 arcminute localizations with 100 counts and $\sim$20 arcminutes with 10 counts.

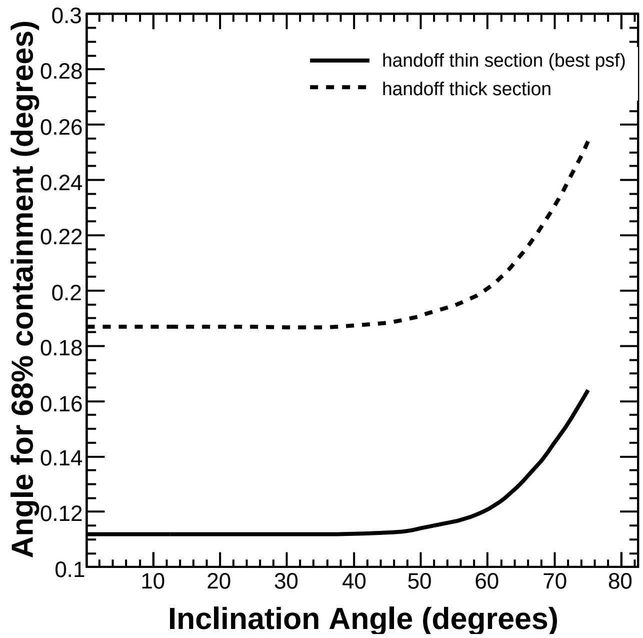

Figure 4: 68% containment of the PSF as a function of incident angle for both the THIN and THICK sections.

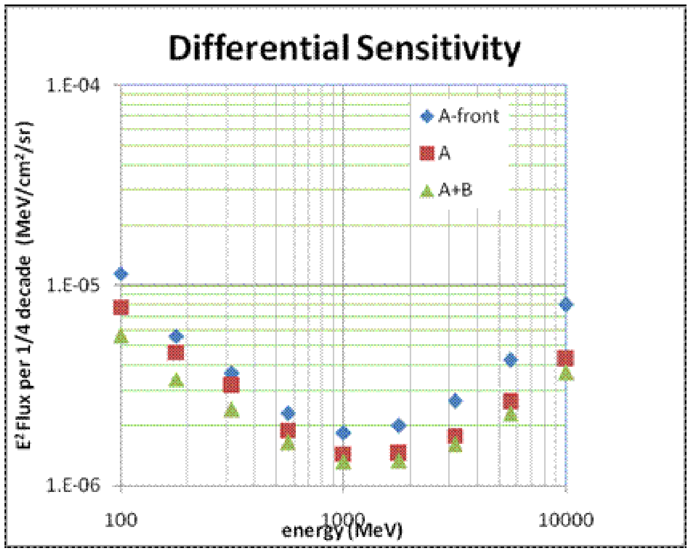

Figure 5: LAT point source sensitivity using *only* the photons in each energy bin separately.

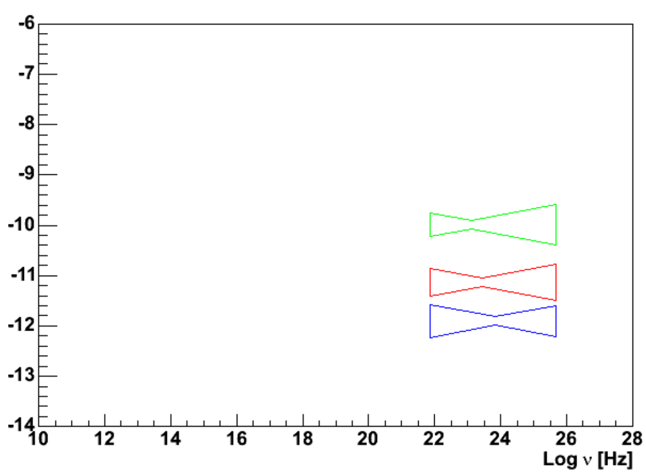

Figure 6: LAT bowtie plot.

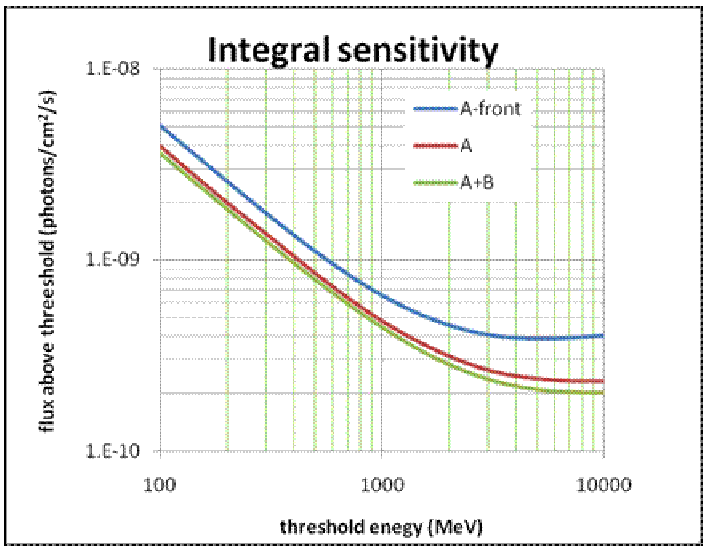

Figure 7: LAT integral sensitivity.

5 The GLAST Burst Monitor (GBM)

5.1 Experimental Objectives

The GBM was added to the GLAST observatory to relate the LAT's gamma-ray burst observations in the 20 MeV to >300 GeV range to the well-studied burst phenomena in the 10 keV to 1 MeV range, and to provide continuous spectral coverage. Thus the sensitivity and FOV of the GBM and the LAT are commensurate to ensure that many bursts will have simultaneous low-energy and high-energy measurements with similar statistical significance.

The burst spectra observed by EGRET above 20 MeV could usually be described by power law spectra, while below ~ 2 MeV the burst spectra observed by BATSE were described by a smoothly broken power law with a characteristic energy of ~ 150 keV. While in many cases the spectrum below ~ 2 MeV appeared to extend above 1 GeV when data from BATSE and EGRET were combined, in some bursts the EGRET observations indicated the presence of additional temporal and spectral components. Therefore, the GBM will show whether the LAT is observing an additional spectral component, and whether the emission > 20 MeV continues after the lower energy emission has ended. The combined GBM and LAT energy range will span more than 7 energy decades from 10 keV to >300 GeV; the LAT and GBM energy bands overlap for inter-instrument calibration.

Burst localizations have historically been crucial to understanding the burst phenomenon, by enabling multi-wavelength observations and by identifying the burst's host galaxy. The GBM will localize bursts to the few degree range. This localization will be downlinked to the ground and disseminated to telescopes around the world in approximately 15 s. The GBM's localization will also be transmitted to the LAT, assisting the LAT localize the burst's high energy emission to a fraction of a degree. If the burst is sufficiently strong, the GBM will request that the spacecraft repoint towards the burst position for 5 hours for LAT afterglow observations.

The GBM collaboration includes scientists from the Marshall Space Flight Center (MSFC), the Max Planck Institute for Extraterrestrial Physics (MPE), the University of Alabama in Huntsville (UAH), the Universities Space Research Association (USRA), and Los Alamos National Laboratory. The MSFC, UAH, and USRA scientists are housed at the National Space Science and Technology Center (NSSTC). The collaboration PIs are Dr. C. A. Meegan (MSFC) and Dr. J. Greiner (MPE)

5.2 GBM Instrumentation

To achieve the GBM performance that will complement the LAT's burst observations, the design and technology borrow heavily from previous GRB instruments, particularly from BATSE on *CGRO*. Like BATSE, the GBM uses two types of cylindrical crystal scintillation detectors, whose light is read out by PMTs.

An array of 12 sodium iodide (NaI) detectors (0.5 in. thick, 5 in. diameter) will cover the lower end of the energy range up to ∼1 MeV. The GBM will trigger on the rates in the NaI detectors. Each NaI detector consists of the crystal, an aluminum housing, a thin beryllium entrance window on one face, and a 5 in. diameter PMT assembly (including a pre-amplifier) on the other. These detectors are distributed around the GLAST spacecraft with different orientations to provide the required sensitivity and FOV. The cosine-like angular response of the thin NaI detectors will be used to localize burst sources by comparing rates from detectors with different viewing angles. To cover higher energies, the GBM also includes two 5 in. thick, 5 in. diameter bismuth germanate (BGO) detectors. The combination of the BGO detectors' high-density (7.1 g cm^{-3}) and large effective Z (∼63) result in good stopping power in the regime overlapping the LAT energy range at ∼20 MeV. The BGO detectors are placed on opposite sides of the GLAST spacecraft to provide high-energy spectral capability over approximately the same FOV as the NaI detectors. For redundancy, each BGO detector has two PMTs located at opposite ends of the crystal.

The signals from all 14 GBM detectors (12 NaI and 2 BGO) are collected by a central Data Processing Unit (DPU). This unit digitizes and time-tags the detectors' pulse height signals, packages the resulting data into several different types for transmission to the ground (via the GLAST spacecraft), and performs various data processing tasks such as autonomous burst triggering. In addition, the DPU is the sole means of controlling and monitoring the instrument. For example, the DPU controls the PMTs' power supply to maintain their gain.

5.3 Data Acquisition

There are three basic types of GBM science data: (1) continuous data consisting of the count rates from each detector with various (selectable) energy and time integration bins; (2) trigger data containing lists of individually time-tagged pulse heights from selected detectors for periods before and after each on-board trigger; and (3) Alert Telemetry containing computed data from a burst trigger, such as intensity, location, and classification. The Burst Alert, the first packet of the Alert Telemetry, will arrive at the Gamma-ray burst Coordinates Network (GCN) within ∼15 s of an instrument triggering. Alerts originating in the GBM will also be sent to the LAT to aid in LAT GRB detection and repointing decisions. The remaining data types will be transmitted via the scheduled Ku-band contacts. The GBM is expected to produce an average of 1.4 Gbits/day, with a minimum of 1.2 Gbits/day and a maximum allocated rate of 2.2 Gbits/day.

The main GBM operating modes, continuous and burst trigger, correspond to the type of data being collected and transmitted. Additional modes will be used in response to anomalies.

1. Continuous mode will be the normal operating mode of the instrument. All instrument voltages will be on, and the continuous data types will be acquired and transmitted. Pre-trigger event data will be acquired but not transmitted to the ground. The data products are the number of counts

accumulated in two different sets of energy and time bins.

2. Burst trigger mode will be enabled upon command from the autonomous burst trigger software, or by direct command from the spacecraft. In addition to the continuous data types, the trigger data types will also be acquired and transmitted. Instrument voltages will be unaffected. The instrument will return autonomously to continuous mode under software control.

5.4 GBM Sensitivity

5.4.1 Detector Effective Area

The GBM's instrument response is calculated using computer simulations that are calibrated by comparison with experimental data. The detected burst flux has three components. First, the direct component is the burst photons that impinge directly on the scintillating crystals. The second consists of photons that scatter off the surrounding material—the spacecraft, the LAT, or the GBM housing. The final component (and the most difficult to calculate) is the photons that scatter off the Earth's atmosphere before being detected by the GBM. In flight the instrument response for a given burst will include all three components; a particular burst-Earth-detector geometry will apply. The effective area and sensitivity curves shown here include only the direct component.

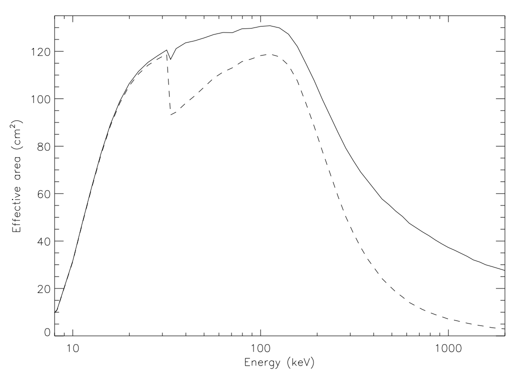

Figure 8: The total (solid) and photopeak (dashed) effective areas for the GBM's NaI detectors are shown as a function of energy.

5.4.2 Background

The burst photons will be observed on top of a substantial background. At low energies (e.g., <100 keV) this background is predominantly photons from the cosmic X-ray background, while at higher energies the background is induced

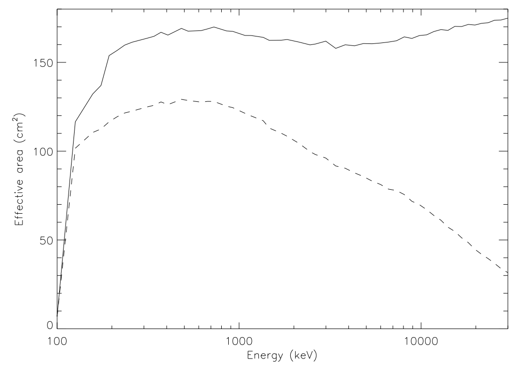

Figure 9: The total (solid) and photopeak (dashed) effective areas for the GBM's BGO detectors are shown as a function of energy.

by the particle flux, either directly or by activation. The background varies in a complex manner over the spacecraft orbit, with the solar cycle, and as a result of the gradual activation of the spacecraft and detector materials. Before launch the background model is scaled from the BATSE background.

5.4.3 Burst Trigger

The GBM will use rate triggers that monitor the count rate from each detector for a statistically significant increase. Similar to BATSE, the GBM as a whole will trigger when two or more detectors trigger. The rate trigger compares the number of counts in an energy band ΔE over a time bin Δt to the expected number of background counts in this ΔE–Δt bin; the background is estimated from the rate before the time bin being tested. As currently planned, the GBM trigger will use only the twelve NaI detectors with one energy bands—ΔE=50–300 keV—and five time bins—Δt =0.016, 0.064, 0.256, 1.024, and 4.096 s. Note that the BATSE trigger had one energy band—usually ΔE=50–300 keV—and the three time bins Δt =0.064, 0.256, and 1.024 s.

5.4.4 Burst Detection Sensitivity

The GBM's sensitivity is the minimum peak flux that will trigger the detectors. This threshold peak flux depends on the values of ΔE and Δt of the rate trigger, the background at the time of the burst, and the burst's spectrum during Δt. Since the sensitivity is calculated as a function of an assumed spectrum, the peak flux used to report the burst sensitivity need not be integrated over ΔE; if the peak fluxes from different detectors are integrated over the same energy band—for example, the 1–1000 keV band—then the sensitivities can be compared for different triggers and different detectors in terms of a common quantity.

The burst spectrum in these sensitivity calculations is parameterized in terms of the 'Band function,' a smoothly broken power law that is characterized by low and high energy spectral indices α and β, and the peak energy E_p, the photon energy at the peak of $E^2N(E) \propto \nu f_\nu$. The figures compare the BATSE and GBM sensitivities as a function of E_p for three different sets of the spectral indices. A trigger threshold of 4.5σ in the second most brightly illuminated GBM detector is assumed. The maximum BATSE sensitivity and the GBM sensitivity along the LAT axis are shown for $\Delta t = 1.024$ s. As expected given the relative size of the detectors (2025 cm^2 for BATSE as opposed to 127 cm^2 for a GBM NaI detector), BATSE was significantly more sensitive than the GBM will be.

Note that these curves do *not* show the sensitivity of the detectors at a particular photon energy, but instead show the threshold peak flux for bursts with a given peak energy E_p.

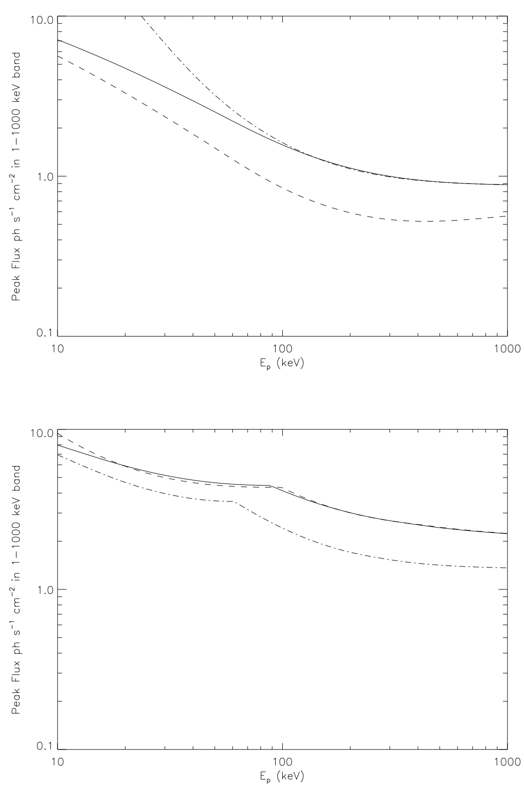

Figure 10: Maximum detection sensitivity for BATSE (top) and the GBM's NaI detectors (bottom). Solid line—$\alpha = -1$, $\beta = -2$; dashed line—$\alpha = -0.5$, $\beta = -2$; dot-dashed line—$\alpha = -1$, $\beta = -3$.

The GBM will trigger on accumulation times Δt as short as 0.016 s (vs. BATSE's shortest $\Delta t = 0.064$ s) and as long as 4.096 s (vs. BATSE's longest $\Delta t = 1.024$ s). The greater range of Δt should increase the sensitivity to both short and long duration bursts, if they exist.

Figure 11 shows a semi-analytic assessment of the increase in sensitivity resulting from the range of Δt values used by the GBM The burst lightcurve is assumed to be proportional to $h(t) = \exp[-t/\tau]$ where the duration $T_{90} = \tau \ln 10$ (T_{90} is the time interval during which 90% of the counts are observed). The curves are the ratios of the threshold peak fluxes as a function of the duration for the actual set of Δt values vs. $\Delta t = 1$ s.

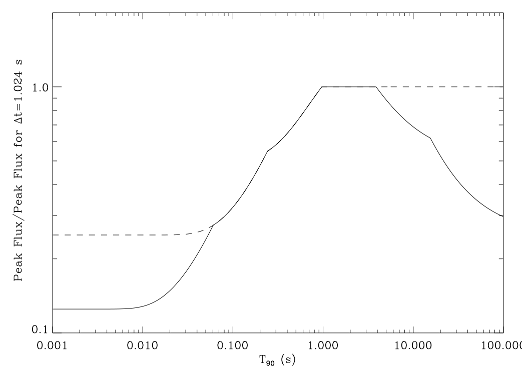

Figure 11: Ratio of the threshold peak flux for a detector's set of accumulation times Δt to the peak flux for Δt=1 s as a function of the burst duration T_{90}. The solid curve is for the GBM NaI detectors while the dashed curve is for BATSE. An exponential lightcurve is assumed.

5.4.5 Burst Localization

The GBM will localize bursts by comparing the rates in the different NaI detectors. The sensitivity of these detectors is approximately proportional to the cosine of the angle between the burst and the detector normal. The 12 NaI detectors are oriented in different directions, thus the expected rates in each detector is a function of the burst direction. The localization is complicated by the scattering of burst photons off the spacecraft and the Earth's atmosphere, and is limited by the statistical fluctuations in the actual count rate. Thus, the localization will improve (smaller uncertainty) as the burst intensity increases.

The GBM will localize bursts onboard the spacecraft as the counts are accumulated. Because of limited computer resources, this localization will use tables of the relative detector count rates as a function of angle for a standard burst spectrum and include the scatter off the Earth's atmosphere assuming GLAST is zenith-pointing. Since the intensity and duration of the burst is unknown until the burst is clearly over, the GBM will calculate positions onboard up to five times using the available counts. The localizations and the count rates used for the localization will be downlinked on a timescale of ∼15 s to the Burst Alert Processor (BAP). The BAP will distribute the positions over the GRB Coordinates Network (GCN). The BAP will also use the downlinked counts from each detector to calculate a more accurate position using a methodology that includes the actual orientation of GLAST relative to the Earth (for the scatter off the Earth's atmosphere) and the observed burst spectrum. This localization on the ground will also be disseminated by GCN. Finally, the GBM instrument team will calculate the most accurate position using the count data downloaded during a regular Ku band downlink.

The average GBM statistical location uncertainty for all detected GRBs is estimated to be $\sim 15^\circ$ (1σ radius), improving to $\sim 9^\circ$ ($\sim 1.5^\circ$) for the brightest 40% (5%) of the bursts. The systematic location error is estimated to be ∼5–10° for on-board processing and ∼1–2° for final ground processed data.

5.4.6 Spectra

For bright GRBs, the combination of GBM and LAT measurements will constrain the time-averaged burst spectrum over more than five energy decades with typical statistical uncertainties for the spectral parameters of less than 1% (∼2–10% for GRBs dimmer by a factor of ten). In addition to measuring low-energy spectra below the LAT threshold, the GBM will significantly improve the constraints on high-energy spectral behavior compared to those of the LAT alone. The combination of GBM and LAT data will therefore provide a powerful tool to study GRB spectra and their underlying physics.

Figure 12 shows simulated GBM and LAT spectra for a strong burst using current effective area curves. As can be seen, the energy bands of the different detectors overlap.

5.4.7 Expected Number of Bursts Detected

The number of bursts that the GBM will detect must be extrapolated from the BATSE burst sample, which is the largest, best characterized sample. Fortunately, the BATSE detectors and the GBM NaI detectors have (had) similar energy sensitivities. The GBM trigger will use more values of the accumulation time Δt than BATSE did, increasing the sensitivity to both short and long duration bursts (see Figure 11); an accumulation time matched to the burst duration will maximize the signal-to-noise ratio. Extrapolating from the BATSE data we estimate the GBM should detect ~ 200 bursts yr^{-1} onboard.

The count rates from all the detectors will be downlinked to the ground with different temporal and spectral resolution. The current plan is to provide the rates in 8 energy channels every 0.256 s and in 128 channels every 8.192 s. Ground analysis of these rates may detect bursts that did not trigger onboard; ground analysis could be more sensitive because of improved background subtraction, consideration of scattering off the Earth's atmosphere, inclusion of

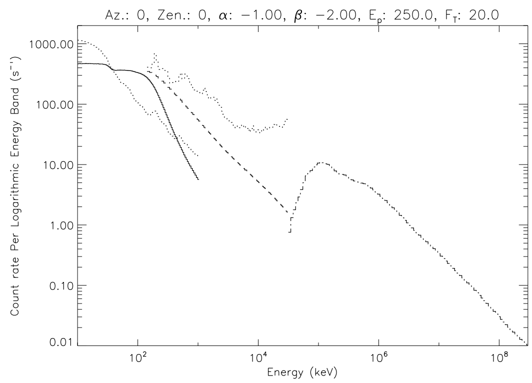

Figure 12: Simulated burst spectrum (count rate per logarithmic energy band) as might be observed by the GLAST detectors: a GBM NaI detector (solid curve), GBM BGO detector (dashed curve), and the LAT (dot-dashed curve). The dotted curves show background models for the GBM's NaI (left curve) and BGO (right curve) detectors. The simulated burst was on the LAT normal with a spectrum described by the 'Band' function with $\alpha = -1$, $\beta = -2$, $E_p = 250$ keV, and $F_T = 20$ ph s^{-1} cm^{-2}.

more than two detectors in the analysis, and human inspection of burst candidates. We estimate that a ground search could increase the burst detection rate by $\sim 40\%$. A search for bursts that were not detected onboard is currently not part of the GIOC's Level 1 pipeline.

A detectable flux in the LAT is not expected for many of the GBM-detected bursts if the 10–1000 keV spectral component can be extrapolated to GeV energies; however, additional spectral and temporal components are expected.

6 The Ground System and Data Flow

6.1 The Mission Operations Center

The MOC is the interface to the spacecraft. The MOC is located at GSFC, and will be staffed after GLAST's launch by the Flight Operations Team (FOT). The MOC will maintain the link to the spacecraft, receive all the data from the spacecraft, monitor the performance of the spacecraft, format and uplink commands and revised flight software to the spacecraft, detect and resolve anomalies, perform Level 0 processing of all the data from the spacecraft, and distribute the resulting data to the other ground elements. The MOC will be staffed by the FOT 8 hours a day, 5 days a week (i.e., during business hours); in the event of a Target of Opportunity (TOO) or an anomaly, a member of the FOT will be paged to come to the MOC when the MOC is not staffed.

6.2 The Instrument Operations Centers

Each instrument team will operate an Instrument Operations Center (IOC). After launch the IOCs will perform 'Level 1' processing of the Level 0 data received from the spacecraft through the MOC. Level 1 processing begins with the output from the instruments (e.g., the energy deposited in a detector component) and ends with data amenable to astrophysical data analysis (e.g., spectral analysis); Level 1 processing also extracts housekeeping data. The science data will be transmitted to the GSSC for dissemination to the scientific community and will be retained for scientific analysis by the instrument teams. Using the housekeeping data in the data the IOCs will monitor instrument performance. Commands to optimize and maintain the instruments will be generated by the IOCs and uplinked to the spacecraft by the MOC; the GSSC will vet the commands' execution time to ensure that the commands do not interfere with the observing schedule.

Before launch the IOCs are responsible for developing the Instrument Response Functions (IRFs) as part of instrument calibration. They will also construct the Level 1 processing pipelines and develop the science analysis tools in conjunction with the GSSC. At the beginning of the mission, the IOCs will refine the processing pipeline based on the on-orbit performance.

Note that in the GLAST model of the ground system, the instrument teams are responsible for the routine processing of the data from their instruments.

6.2.1 LAT Instrument Operations and Science Center (ISOC)

The ISOC, the LAT's IOC, is located at SLAC, the LAT's PI institution. In addition to the IOC responsibilities described above, the ISOC will be responsible for maintaining a model of the Galactic interstellar and extragalactic diffuse emission, which is the background against which point sources are detected and analyzed (this emission is of course intrinsically interesting). Periodically the ISOC will send the GSSC an updated model.

The ISOC will support mirror data sites associated with their Italian and French instrument teams members.

6.2.2 GBM Instrument Operations Center (GIOC)

The GIOC is located at the National Space Science and Technology Center (NSSTC) in Huntsville, AL. The GIOC will support a mirror data site associated with its German instrument team members. The GIOC is also responsible for the Burst Alert Processor (BAP), GLAST's interface with the Gamma-ray burst Coordinates Network (GCN), as is described below.

6.3 The GLAST Science Support Center (GSSC)

The GSSC is the interface between the GLAST mission and members of the scientific community unaffiliated with the instrument teams; therefore it has the responsibility of organizing and administering the GI program and of providing GIs and other scientists with data, analysis software and related information. The GSSC will maintain databases of various data products for use during the mission; these databases will become the mission archives in the HEASARC at the end of the mission. The GSSC will also plan the science observation timelines and support science operations decisions such as TOO observations. Additionally, the GSSC will support the Project in running various aspects of the mission.

The GSSC combines the functions often performed by a Science Operations Center—which carries out high level data processing, archiving and mission planning—and a Guest Observer Facility—which supports GIs. Note that the GSSC does not carry out Level 1 processing. Given the wide availability of computers and the immediacy of e-mail, the GSSC will not support a dedicated facility to which investigators come to obtain and analyze data.

The GSSC assists the Project Scientist in organizing the meetings of GLAST-related committees such as the Users' Group (see §3.5), as well as scientific workshops and conferences the project will convene.

The GSSC is located in the Astrophysics Science Division (ASD) at GSFC, where it is a mission-specific constituent of the Office of General Investigator Programs (OGIP). OGIP coordinates all guest observer programs and related activities within ASD. It consists of the HEASARC and support centers for other missions that will operate concurrently with GLAST such as INTEGRAL, Swift, XMM-Newton, Suzaku and RXTE. By co-locating the GLAST GSSC with other support centers and the HEASARC, the GSSC will use common resources such as web services, archival services, data backup, database servers and data/software standards.

6.4 The Gamma-ray burst Coordinates Network (GCN)

The GCN is a system operated by NASA/GSFC that distributes the locations of GRBs detected by spacecraft and the reports of follow-up observations made by ground-based optical and radio observers. The first function initiates follow-up observations as rapidly as possible while the second informs the astrophysical community about the burst. See http://gcn.gsfc.nasa.gov.

When a mission such as GLAST detects and localizes a burst, the burst location is transmitted to the GCN which then disseminates the location and other pertinent information as a fixed format GCN Notice. As desired by the subscriber, the Notice can be sent as an e-mail, a message through an internet socket or a page. In general, there are no humans involved from the detection of the burst until the Notice arrives at the subscriber, and in many cases a robotic telescope responds autonomously to the Notice.

Observers can report their results as GCN Circulars, which are similar to IAU Circulars. These are free format messages that are e-mailed to the GCN by registered observers, and then disseminated to subscribers by e-mail. The GCN Circulars are also posted on the GCN website.

The GLAST-generated GCN Notices will be archived at http://gcn.gsfc.nasa.gov/glast_grbs.html. The GLAST-generated GCN Circulars will also be archived.

6.5 The High Energy Astrophysics Science Archive Research Center (HEASARC)

The HEASARC is also a constituent of the OGIP at NASA/GSFC. It is one of three NASA wavelength-specific research archives (the others are the Infrared Science Archive (IRSA) for infrared data and the Multimission Archive at Space Telescope science institute—MAST—for UV/optical data). The National Space Science Data Center (NSSDC), also at GSFC, is the "deep archive." These centers support active missions and sustain in usable form archival data from missions that have ended. The archives are co-located with scientists actively undertaking research, connecting the data with the necessary science expertise. The multi-mission approach to the archives leads to cost savings and a uniform analysis environment for future missions by reusing software and archive resources. These data centers coordinate data, software and media standards for space astrophysics.

In particular, the HEASARC maintains standards for file formats (see the §8) and analysis software (see §9). The analysis software includes familiar tools such as XSPEC. The BROWSE interface is the data portal to the HEASARC data archives for a large number of high energy astrophysics missions.

The GSSC maintains its databases and its website on HEASARC servers, and avails itself of the HEASARC archives and software infrastructure. Indeed, the GSSC will ingest nearly all the science data products into the HEASARC's data system and will serve these data to the scientific community through the HEASARC's Browse interface. Thus, when the GSSC is disbanded at the end of the mission, the GSSC's databases will remain in the HEASARC as the GLAST mission's permanent archives.

7 Mission Operations

7.1 Observing Modes

The LAT has a very wide FOV and consequently, most of a given source's data will not be accumulated while the source is near the LAT's normal. Thus LAT data will not consist of a series of discrete observations, but a continuous list of counts from over the entire sky. Nonetheless, the LAT's pointing will determine when different parts of the sky are observed. There are two basic observing modes: survey and pointed.

The pointing accuracy will be $< 2^\circ$ (1σ, goal of $< 0.5^\circ$), with a pointing knowledge of <10 arcsec (goal <5 arcsec).

The observatory will be very flexible in the direction in which it can point. While there will be few constraints based on spacecraft and instrument safety, to maximize exposure to astrophysical sources, the observing schedule will generally avoid pointing the LAT at or near the Earth (i.e., to avoid occultation of part of the LAT's FOV); however, for instrument calibration the LAT may occasionally observe the Earth's limb to detect albedo gamma rays produced in, or scattered off, the Earth's atmosphere. Orientation requirements for the LAT's cooling radiators and the observatory solar panels may impose engineering constraints, particularly during slewing maneuvers. No science data will be taken when the observatory is in the South Atlantic Anomaly (SAA—a region of high particle background).

Transitions between observing modes may be commanded from the ground or by the spacecraft. Commanded mode changes may be requested by the instrument teams, GIs (after Cycle 1) or the Project Scientist, and implemented following appropriate review by the IOCs, the GSSC and the MOC. Based on the detection of a burst by the LAT or the GBM, the LAT instrument can request autonomous repointing of the spacecraft and change the observing mode to monitor the location of a GRB (or other short timescale transient) in or near the LAT's FOV. After a pre-determined time the spacecraft will return to the scheduled mode.

7.1.1 Survey Mode

In survey mode the LAT will be pointed at a fixed "rocking" angle relative to the zenith (the point directly opposite the Earth) perpendicular to the spacecraft velocity vector. Once per orbit the pointing will be slewed from one side of the orbital plane to the other, resulting in a two orbit periodicity that maximizes sky uniformity on a short timescale. The current default rocking angle is 35° (the maximum angle is 60°). The figure-of-merit to be optimized by a particular rocking profile is nominally uniformity of sky coverage, but may change as the mission progresses. Survey mode will most likely predominate, at least during the early part of the mission, because it will satisfy most scientific objectives simultaneously.

In the second and subsequent cycles GIs will be able to propose modified survey observations.

7.1.2 Pointed Mode

When justified by the demands of a particular investigation, the LAT will be pointed at a target. In the second and subsequent cycles GIs may request pointed observations. A pointed observation may be optimum for pulsar timing studies (to reduce the effect of variations in a pulsar's period) or for other studies where building up exposure over a short time will be useful. The timeline will be constructed to keep the earth out of the FOV, and thus the observatory will usually observe a secondary target when the Earth occults the primary target. The default Earth Avoidance Angle (the angle between the +z axis and the Earth's limb) is 30°. The spacecraft flight software can autonomously keep the Earth's limb out of the Earth Avoidance Angle.

TOO observations and autonomous repoints to the position of a gamma-ray burst are examples of pointed observations.

7.2 Operating the GLAST Spacecraft

The GLAST ground system will operate the GLAST observatory by creating and uploading commands, and by monitoring the performance of the spacecraft and its instruments. The different ground system components have specific roles in operating the spacecraft, but ultimately only the MOC will send commands to the spacecraft. The mission will be operated predominantly through weekly command uploads, although occasionally additional command uploads will be required to update flight software. In addition, command uploads to implement TOO observations will be performed on varying timescales based on the observation urgency.

7.2.1 The Long-Term Science Timeline

The GSSC's timeline creation process begins with producing a long term timeline for an entire GI cycle; in this timeline observations are scheduled down to the week timescale. During the first year of scientific operations the timeline will be simple: GLAST will conduct an all-sky survey that will be interrupted only by Project Scientist-approved TOO observations and autonomous repointings following transients and GRBs.

7.2.2 The Weekly Command Load

The GSSC will create weekly science timelines implementing the observations planned for that week in the long term timeline. Because of the long lead time necessary to schedule TDRSS Ku band contacts (the primary data downlink), a preliminary science timeline must be created and sent to the MOC about three weeks before its implementation. The MOC will then schedule TDRSS contacts, providing the GSSC a contact schedule approximately a week before implementation. The GSSC will refine the science timeline, particularly by adding instrument commands received from the IOCs, and resubmit the final science timeline to the MOC a few days before implementation. In general the final science timeline can alter the observations included in the preliminary science timeline as long as the scheduled TDRSS contacts are not disrupted; because of the margin on the scheduled TDRSS contacts (i.e., more contact time will be scheduled than required) the GSSC may revise the schedule and miss a TDRSS contact if necessary, after consulting with the MOC. GLAST's Ku band antenna is on the earth side of the spacecraft while the TDRSS satellites are in geosynchronous orbit (i.e., much higher than GLAST's orbit), and therefore Ku contacts are possible only at specific orientations of GLAST and the TDRSS satellites.

At the end of week covered by a command load the MOC will create the as-flown timeline, which the GSSC will compare to the science timeline, noting observations that were pre-empted or shortened by TOOs or autonomous repointings.

Thus an investigator can determine the week during which an observation is planned months before the observation. Approximately three weeks in advance a preliminary time for a given observation will be available, but the scheduling will not become definitive until a week beforehand. Whether the observation occurred will not be known until the planned and as-flown timelines are reconciled. All the above-mentioned timelines will be archived by the GSSC, and the science and as-flown timelines will be accessible on the GSSC website. The tool at http://glast.gsfc.nasa.gov/ssc/resources/timeline/posting/timeline_search.php allows the user to select and display different quantities from the most current timeline available for the specified time period.

7.2.3 Additional Command Loads

If needed, commands and flight software upgrades can be uplinked in between the uplinks of the weekly command load. Some of these commands may be executed in real time. The GSSC will insure that such real time commands do not disrupt an observation; however, the GSSC will pass a command immediately to the MOC if an IOC marks it as very high priority (e.g., if the safety of the instrument is an issue). Large flight software upgrades and time critical commands (e.g., to save an instrument or the observatory) will be uplinked through TDRSS Multiple Access Facility (MAF). While non-critical commands can be uplinked at any time, implementing commands through the weekly observatory timeline will be preferred.

7.2.4 Target-of-Opportunity (TOO) Operations

The GLAST Project Scientist (or his/her designee) may declare a TOO observation because: an approved GI's TOO criteria have been satisfied (after Cycle 1); a source is undergoing an extreme variation (e.g., a giant radio flare); or a scientific discovery or development justifies an immediate observation. TOO requests will be submitted to the Project Scientist through the GSSC website using the Remote Proposal System (RPS). The requester will justify the TOO. The Project Scientist (or his/her designee) will ask the GSSC whether a TOO is feasible. The GSSC will consider observational constraints (if any) and the impact on the timeline.

Within 2 hours after the Project Scientist or his/her designee authorizes a TOO, the GSSC will send to the MOC a TOO order defining the TOO, and will notify the IOCs, the scientist requesting the TOO, and the scientific community (via the GSSC website) of the TOO. The MOC will construct the commands, schedule a TDRSS contact with the spacecraft, transmit the commands to the spacecraft, verify that the commands have been executed, and notify the GSSC of whether the TOO was implemented. The MOC has 4 hours from the receipt of the TOO order from GSSC until the commands are sent to TDRSS. If the MOC is not staffed when the TOO order is issued, a member of the FOT will come into the MOC to implement the TOO order. While these are the required latencies, it is expected that the actual time to upload a TOO will be much shorter.

Not all TOO observations will need to be implemented as soon as possible. If the scientist proposing the TOO observations indicates that the observation is not urgent, the request will be processed during the next business day, and if approved, the TOO observation will be scheduled as an update of the weekly command load. Indeed, a TOO observation that began with a special TOO command uplinked to the spacecraft may be continued by an updated command load.

The threshold for an autonomous repoint of the GLAST observatory (e.g., in response to the detection of a gamma-ray burst) can be modified during a TOO observation. Thus the scientist proposing the TOO observation can request that the observation be interrupted only by a very bright burst.

7.2.5 Autonomous Repoint Requests (ARRs)

If either instrument detects a burst that exceeds predetermined criteria based on burst intensity and spectral hardness, the instrument may send the spacecraft an autonomous repoint request (ARR). If permitted by operational constraints, the spacecraft will then point the LAT at the burst location for a time period, currently five hours, except when the burst location is occulted by the Earth.

Burst occurrence is unpredictable, and therefore the ARR threshold can be varied based on the time criticality of a planned observation.

8 The Data

8.1 Data Levels

The data recorded by the GLAST instruments and by subsequent processing are described hierarchically as a series of levels. Most investigators will analyze the lists of counts from each instrument (considered 'Level 1' data), quicklook results ('Level 2') and catalogs ('Level 3').

8.1.1 Raw Data

Raw data are provided by the spacecraft telemetry to the ground. They may contain duplicate data packets, data packets out of time order, damaged packets, etc. All raw data will be retained at the TDRSS ground station for seven days in case it becomes necessary to retransmit it from the ground station to the MOC for any reason. Raw data will be archived at the MOC for the duration of the mission.

GIs are unlikely to have any need to access the raw data, and therefore no provision has been made to provide these data.

8.1.2 Level 0 Data

Level 0 data will be raw data that has undergone minimal processing. No information will be lost, but duplicate data packets will be removed, quality checks will be made, and the data packets will be time-ordered. The raw data will be decompressed (if necessary) and separated into spacecraft and instrument packets. Performed at the MOC, Level 0 processing converts the raw data into the Level 0 data. Instrument-specific Level 0 data will be archived at the IOCs. The GSSC will keep the Level 0 data for a year and then archive it at the National Space Science Data Center (NSSDC).

GIs are unlikely to have any need to access the raw data, and therefore no provision has been made to provide these data.

8.1.3 Level 1 Data

Level 1 data result from "automatic" pipeline processing of Level 0 data. The resulting Level 1 data are generally the starting point for scientific analyses by the user community and the instrument teams; the specific data products are described below. Level 1 processing of LAT and GBM data will be performed at the ISOC and the GIOC, respectively. The instrument teams will access the resulting Level 1 data at their respective IOCs while the general scientific community will extract the Level 1 data from databases at the GSSC or through the HEASARC's BROWSE system.

In LAT Level 1 processing, the Level 0 data describing the interactions within the LAT will be analyzed to identify and characterize the interacting particles (e.g., photons, electrons, protons, etc.). Thus tracks will be fitted to the hits in the TKR and CAL (see §4.2), the particle trajectories and energies will be calculated, and the event will be classified. The Level 1 data for an event will include at least the event arrival time, apparent energy and apparent origin on the sky. Other LAT Level 1 data will include histories of the instrument livetime and pointing.

GBM Level 1 processing will primarily re-format and reorganize the data. The gains of each detector will be calibrated by monitoring the pulse-height channels of one or more background spectral lines. These gains will then be used to convert the raw detector pulse-height channels to an apparent energy. The Level 1 data will consist of continuous and burst data. Continuous data are the rates in all GBM detectors in different energy bands, regardless of whether a burst has been detected. Burst data are the counts, rates, catalog information (e.g., fluence, duration, peak flux), and ancillary data necessary for analyzing the burst.

8.1.4 Level 2 Data

Level 2 data will result from routine scientific analysis, usually using the science analysis software developed for more focused studies by general scientific community (including GIs) and the instrument teams. For LAT observations these data may include: exploratory science analyses; quick-look analyses to detect transient sources and to support operations planning; standard analysis of transient sources; refined analyses of on-board GRB and AGN transient alerts; and LAT sky maps accumulated over a variety of time intervals. For GBM observations Level 2 data might include the uniform fitting of GRB spectra with standard spectral models.

8.1.5 Level 3 Data

Level 3 data will consist of catalogs and compendia of Level 2 data. The LAT team will produce a catalog of gamma-ray sources, including (but not limited to) flux histories and tentative source identifications. The first LAT catalog will be based on the first-year sky-survey data; updates are to be released following the 2nd and 5th years of operation, and at the end of the mission. To assist investigators prepare GI proposals, a preliminary source list will be released half a year after the beginning of scientific observations. The GBM team will release catalogs of GBM burst energy spectra. Both instrument teams will maintain catalogs of transient events.

8.1.6 Ancillary Data

The LAT team will produce, update and make public the diffuse Galactic interstellar and extragalactic emission models used for the analysis resulting in the LAT source catalogs. As a spatially varying background underlying point sources, the diffuse emission must be included when analyzing point sources. The diffuse Galactic emission is also intrinsically interesting because it results from the interaction of cosmic rays with gas and photons in our galaxy.

The GSSC will maintain a database of pulsar ephemerides resulting from radio and optical monitoring of pulsars likely to be gamma-ray sources.

8.2 LAT Data

In Cycle 1 the fluxes, spectra and lightcurves of ~ 20 scientifically interesting sources and transients (including gamma-ray bursts) will be posted on the GSSC website.

Many additional data products will be released in the second and subsequent cycles, and will be described in future editions of this handbook.

8.3 GBM Data

The processing of the GBM data will result in a number of data products. The average investigator will access some of these data products explicitly, while others will be used by the analysis tools. The set of GLAST-specific tools, called the Standard Analysis Environment (SAE), was developed primarily to analyze LAT data, but includes the capability to analyze GBM burst data.

The GBM data can be divided into four categories. First are the data products that are produced after each burst. Second are the data products produced each day with the count rates from each detector, regardless of whether a burst was detected, and daily calibration data. Third are general calibration data. Finally, the GBM instrument team will produce a number of catalogs.

The following are the data products resulting from each burst; they will be accessed through the Browse interface (with a link to the GSSC website).

CTIME (burst version) For each detector, the counts accumulated every 0.256 s in 8 energy channels.

CSPEC (burst version) For each detector, the counts accumulated every 8.192 s in 128 energy channels.

GBM TTE 'Time-tagged events'—count lists from each GBM detector for each burst in 128 energy channels. Investigators will use this data product for burst spectral-temporal analysis.

GBM DRMs 8 and 128 energy channel detector response matrices (DRMs) for all 14 detectors, corresponding to the energy channels for the CTIME and CSPEC data products.

GBM Trigger Catalog Entry Classification of the GBM triggers with some basic characteristics.

GBM Burst or Spectral Catalog Entry Values of the quantities describing the burst (e.g., durations, fluences).

GBM TRIGDAT All the GBM's messages downlinked through TDRSS.

GBM Background Files Background spectra for spectral fitting.

The following are the daily data products; they will be accessed through the Browse interface (with a link to the GSSC website).

CTIME (daily version) The counts accumulated every 0.256 s in 8 energy channels for each of the 14 detectors.

CSPEC (daily version) The counts accumulated every 8.192 s in 128 energy channels for each of the 14 detectors.

GBM gain and energy resolution history History of the detector gains and energy resolutions; required for calculating DRMs.

GLAST position and attitude history History of GLAST's position and attitude, required for calculating response matrices.

The following are calibration data products; the GBM instrument team will update them periodically. The analysis software will access these files through the CALDB directory structure; the average investigator will most likely not use them directly.

GBM PHA Look-Up Tables Tables of the correspondence between CTIME and CSPEC energy channels and the photopeak energy for each detector.

GBM Calibration Tables of fiducial detector response parameters from which the burst-specific DRMs are calculated.

Finally, the GBM instrument team will produce catalogs that will be accessed through the Browse interface (with a link to the GSSC website). Note that preliminary catalog entries will be provided with the burst data products; these entries will subsequently be updated.

GBM Trigger Catalog Classification of GBM triggers. This catalog includes all GBM triggers, whether or not they result from a burst.

GBM Burst Catalog A detailed description of each GBM trigger classified as a burst, including spectra.

9 The Software

9.1 The Standard Analysis Environment (SAE)

9.1.1 Overview

GLAST's Level 1 data will be analyzed by the Standard Analysis Environment (SAE). The SAE is not a new analysis system but rather an instrument-specific subpackage of the HEASoft tools (e.g., FTOOLS) familiar to the high energy astrophysics community. Thus, the software conforms to the standards of the HEASARC by using FITS format files for I/O, utilizing PIL parameter files, and being built mainly of simple programs that can be run from a command line. The scientific tools do not require expensive proprietary software, and will run on the computer platforms common to the astronomical community. In addition to the usual flavors of UNIX (including Mac OS X), Windows will also be supported.

The SAE will add to the HEASoft system the tools that the GLAST data require. In particular, a likelihood tool will analyze the LAT photon data (i.e., counts) in space and energy. The GLAST tools are written in object-oriented C++, and the libraries developed for GLAST may be used by future HEASoft tools. A GUI interface is planned.

The SAE has been developed primarily for the LAT data, but where applicable the tools have been extended to analyze GBM data. Thus only a few GBM-specific tools are necessary, although the GBM team may contribute additional tools based on their burst analysis experience. Where possible, the tools have been designed to permit multimission analysis.

During the early part of the mission these tools will be provided to GLAST investigators through the GSSC's website, but later in the mission the HEASARC will integrate them into the general HEAsoft system. Regardless of the website, the HEASARC's installation methodology will be used. Users may choose either binary executables or source code. The IOCs will provide the software to the instrument teams.

The SAE tools will be released when the user community needs these tools. Since GBM data will be available from the beginning of science observations (approximately two months after launch, which coincides with the beginning of Cycle 1 of the GI program), the SAE tools useful for GBM data analysis will be released when science observations begin. LAT count data will be publicly available at the beginning of Cycle 2, but scientists preparing GI proposals may need to simulate observations with the SAE's simulation capabilities (as described below), and may want to familiarize themselves with the suite of tools. Therefore, the full set of tools will be released in the middle of Cycle 1, before the Cycle 2 proposal period. A workshop on the use of the SAE is scheduled for the middle of the Cycle 2 proposal period. A major update of the SAE is expected before the LAT count data become public at the beginning of Cycle 2. This software release schedule will permit the LAT instrument team to revise the tools based on experience analyzing flight data.

The documentation for the SAE consists of four components. The first describes how the SAE tools should be installed on the user's system. The second component consists of a series of analysis threads that demonstrate how the tools can be used together for a number of typical analyses. These analysis threads are grouped topically, such as data access, point source analysis, GRB analysis and pulsar analysis. As time progresses additional analysis threads will be added, some contributed by users. The third component is a reference manual describing each tool and its input parameters. The resulting sections are similar to unix 'man' pages or the documentation provided by the fhelp command for the FTOOLs. Finally, the fourth component, called the 'Cicerone' (a cicerone is a sophisticated guide for an intelligent user), is a detailed manual that explains the nature of the data and the methods behind the tools. This set of documentation should support and assistance users with different learning styles and different initial knowledge.

The instrument teams and the general scientific community will use the same basic analysis tools. Consequently, the GSSC and the IOCs have collaborated in defining and developing the SAE. However, GSSC will support the general investigator community's use of the software.

Because the LAT event data will not be released in Cycle 1, the tools to analyze LAT events will not be described in this edition of the Handbook.

9.1.2 Summary of SAE Tools Available in Cycle 1

gtbin This tool bins an event list in time, energy, or space and results in spectra, lightcurves, or a count map.

gtbindef This utility reads in an ASCII file with the time or energy bin definitions, and produces the appropriately-formatted FITS file that can be used by gtbin to bin an event list.

9.2 Simulation Tools

These tools allow a scientist to estimate the detectability of a source and through simulations, determine how well a spectrum can be observed. Thus these tools will be central to the preparation of GI proposals. The tools provide a hierarchy of increasing accuracy but decreasing generality.

The most general tool is a web-based tool that estimates the detectability by the LAT of a point source with a power law spectrum superimposed on the diffuse background. This will probably be the most widely used tool.

The GLAST version of WebSpec allows the user to perform an XSPEC 'fakeit' simulation of either a GBM or LAT observation through a web interface; the tool can be found at http://heasarc.gsfc.nasa.gov/webspec/GLASTspec.html. The result is a simulated spectrum and a fit to this spectrum. The RSP and BAK files provided have built-in assumptions (e.g., the RSP files will be applicable to particular observing modes). The web interface does not permit the user to use all of XSPEC's capabilities, but users can download the RSP and BAK files from the web interface and run XSPEC with these files on his/her server.

Finally, the user can run the SAE tools to simulate an observation and then analyze the results with the likelihood tool. This should be the most accurate simulation, but is specific to the specified observing profile and source model. In general the users will download these tools as part of the SAE. Because investigators will not be able to propose modifications of the observing plan for Cycle 1, they do not need to simulate observations while preparing Cycle 1 proposals, and therefore this simulation capability will not be available in the Cycle 1 proposal period.

9.2.1 Source Detectability Website

The most basic tool for calculating the detectability of LAT sources considers a point source with a power law spectrum observed against a uniform background. Because of its generality, this tool is expected to give only approximate results, particularly before on-orbit experience and calibration is available.

9.2.2 GLAST Version of WebSpec

WebSpec is a web interface to XSPEC for simulating and fitting count spectra (i.e., using XSPEC's 'fakeit' command). The standard version (http://heasarc.gsfc.nasa.gov/webspec/webspec.html) models a large number of X-ray detectors. For most of these detectors a single response matrix and a single background model suffice. GLAST requires a number of response matrices and background models. The response of the two different GBM detectors varies with the burst's angle to the detector. The LAT effective area is a function of the inclination angle, and data will be taken at different angles. The diffuse background against which a source will be observed by the LAT will vary. The emission processes of GLAST sources differs from that of typical X-ray sources, and consequently a different set of spectral models is required. Therefore a GLAST version of WebSpec is provided.

GLASTspec, the GLAST version of WebSpec, can be found at http://heasarc.gsfc.nasa.gov/webspec/GLAST/webspec.html. Instead of a choice of different instruments, you choose a specific GLAST detector in a particular case. Thus, you can choose to model a LAT survey mode observation with three different background levels: at the Galactic pole; at the Galactic equator (but not at the Galactic Center); and at a mid-latitude point. In the future response matrices for LAT pointed observations will be provided (such observations are not relevant for Cycle 1). Alternatively, you can choose to model a burst at one of a number of angles relative to a NaI or BGO detector.

Then you choose a spectral model. Note that the models provided are mostly based on non-thermal mechanisms appropriate for the sources GLAST is anticipated to observe. XSPEC energies are in units of keV; unfortunately, this can introduce strong correlations between spectral parameters.

Finally, you input the observation time. For the GBM cases this should be of order of a burst's duration, i.e., 0.1–1000 s. For the LAT cases this should be the elapsed time in survey mode (see the discussion of time under the detectability tool above); the response matrix averages over the different inclination angles at which data are taken, SAA passages, and deadtime.

When run, the tool will provide fluxes in a number of energy bands, a plot of the simulated spectrum, and a fit of the input model to the simulated spectrum (the uncertainty on the fitted parameters indicate how well an actual observation will determine model parameters). You can download the plot and different data tables to your computer. In addition, you can download the response functions and background files used by GLASTspec so that you can run more sophisticated simulations with XSPEC. For example, you can simulate spectra with spectral models not provided by GLASTspec, or you can fit a simulated spectrum with a model different from the model used to create the spectrum.

9.3 Other Tools

The GSSC and the HEASARC provide a number of other tools that may be useful for preparing proposals and analyzing GLAST data.

9.3.1 Time System Conversion Tool

Different tools use different time conventions and formats. Most of the GLAST tools and files Mission Elapsed Time (MET), the number of seconds since midnight, January 1, 2001 (UTC), a number that will have at least 7 digits. Observations by other observatories often use Julian days. However, most humans experience time in terms of calendar days. Therefore, investigators may find the xTime tool at http://heasarc.gsfc.nasa.gov/cgi-bin/Tools/xTime/xTime.pl useful. In using this tool a user inputs the time in one particular time system or format, and the tool calculates the time in a large number of other systems. Note that the user indicates whether the input or output are in UTC or TT at the bottom of the tool.

9.3.2 Timeline Posting Tool

After launch investigators may need to know when a pointed observation is planned or has occurred, or which observation is planned at a particular time. Therefore past and future observing timelines can be queried at http://glast.gsfc.nasa.gov/ssc/resources/timeline/posting/timeline_search.php.

9.3.3 TOO Status Posting Tool

Scientists interested in the status of an accepted TOO observation can query the GSSC TOO databases through the website at http://glast.gsfc.nasa.gov/ssc/resources/timeline/too/. The TOO observation will be identified by an observation ID. The scientist who requested the observation will receive this ID in the e-mail notifying him/her that the TOO request has been accepted. Other scientists can query the GSSC TOO databases through this website to learn about all accepted TOO requests.

Once a particular TOO observation has been identified, the tool returns the current status of the TOO observation. Thus immediately after the TOO request has been accepted the posting tool will only report that the request has been accepted, along with basic information about the planned observation (e.g., source location and observation duration). As time progresses, the report will include notifications that the GSSC has ordered the observation and that the MOC has received and implemented the order.

10 Proposal Submission

10.1 Notice of Intent (NOI) Submission

Potential proposers can assist the GSSC plan for the proposal peer review by submitting a Notice of Intent (NOI) for each proposal by July 13, 2007. These NOIs are optional, and scientists are encouraged to submit a proposal even if a NOI was not submitted, and a NOI may be submitted after July 13. A NOI can be submitted through http://glast.gsfc.nasa.gov/ssc/proposals/cycle1/noi/. See §10.4 for a description of 'Subject Category,' 'Observation Type' and 'Proposal Type.'

10.2 RPS Registration

Phase 1 GI proposals (e.g., the scientific justification) and TOO observation requests will be submitted through the HEASARC's Remote Proposal System (RPS). But first you must create an account for the Astrophysics Knowledge Base for Analysis and Reporting (AKBAR) system at http://heasarc.nasa.gov/akbar/join/. You must then join the GLAST GI ('GLAST Guest Investigator RPS (GLAST)') and TOO ('GLAST Target of Opportunity RPS (GLASTTOO)') groups. When you create an AKBAR account you will be able to choose the AKBAR groups you wish to join. Alternatively, you can modify your group membership when you log into AKBAR.

It would be wise to create this AKBAR account in advance to avoid last minute surprises in submitting a proposal just before the deadline or requesting a TOO observation in the middle of the night.

10.3 NSPIRES Registration

A NASA Solicitation and Proposal Integrated Review and Evaluation System (NSPIRES) form must be submitted only for a phase 2 GI proposal, which is a budget proposal that is submitted only if your phase 1 GI proposal (the scientific justification proposal submitted through RPS) has been tentatively accepted. Nonetheless, if you will submit a phase 1 GI proposal, you must be registered with NSPRIRES before the proposal deadline. Although you will not submit the phase 1 proposal through NSPIRES, basic data in the NSPIRES database will be used to track your phase 1 proposal.

You become a registered NSPIRES user through the http://nspires.nasaprs.com/external/aboutRegistration.do webpage. Note that your home institution, the institution through which you plan to submit a budget proposal should your phase 1 proposal be tentatively accepted, must also be registered with NSPIRES. Again, it is wise to register with NSPIRES well in advance of any deadlines to avoid last minute surprises (such as discovering that your home institution is not yet registered with NSPIRES).

10.4 RPS GI Proposals

Note that you must have an AKBAR account and be a member of the 'GLAST Guest Investigator RPS (GLAST)' group to submit a phase 1 GI proposal through RPS.

After logging into AKBAR, click on 'GLAST Guest Investigator RPS (GLAST).' This will lead you to a webpage from which you can submit a new proposal, or modify an existing proposal. Choose to submit a new proposal. Most of the fields are self-explanatory (and there is an accompanying help page that is accessed by clicking on the field title).

The 'Subject Category' is the type of object you wish to study (e.g., AGN); your choice will guide the assignment of your proposal to the appropriate peer review panel.

You have two choices under 'Proposal Type:' 'regular' and 'large' (see §3.2). The research program for regular proposals can be performed in one year, while the research program for large proposals may require up to three years and greater funding. While large proposals may include a multi-year research plan, progress reports must be submitted every year, with the expectation that renewals will be funded if sufficient progress has been made on the research plan.

There are four choices under 'Observation Type:' 'Correlated,' 'Data Analysis Techniques,' 'GBM Analysis,' and 'Theory.' 'Correlated' covers the analysis of data from multiwavelength observations at other wavelengths or released LAT summary data. Target forms must be filled out for all proposals that use data from specific sources; the target forms will identify proposals for similar analyses on the same sources (e.g., two optical monitoring campaigns on the same blazar). Since 'correlated' proposals presumably deal with specific sources, at least one target form must be filled out. Target forms may be filled out for the other types, if needed (e.g., a new data analysis technique is tested on data from a source).

If you are applying to one of the joint proposal programs (described below), you should click the 'yes' button after 'Joint Proposal?' and then select the program from the pull-down menu. The NRAO and NOAO programs have additional fields on the RPS form.

In lieu of submitting a detailed budget with the first phase of your GI proposal, you must provide the maximum budget request. This single number is entered on the RPS form in thousands of dollars; thus enter '50' if you intend to request $50,000. This is the *only* place that you provide the budget number; do not include it in your scientific justification. If you are submitting a multi-year large proposal, enter the budget for the first year only. Also, you must provide the number of NASA civil servant FTEs (possibly a fraction) that will be supported by the proposal should it be accepted.

You may save your draft proposal to your computer (using the 'Save' button) before submitting the proposal; your draft proposal can be reloaded from your computer (using the 'Reload' button). You can upload an ASCII file with a list of targets by using the 'Add Targets' button. Finally, you can check whether all the entries are filled in correctly by clicking on the 'Verify' button; any errors will be reported at the top of the form.

Remember to submit the proposal (using the 'Submit' button) before the deadline! Your proposal will then be loaded into a database for further consideration. When you submit the proposal, you will be shown the proposal form you just submitted. To upload the PDF file with the scientific justification (4 pages for regular proposals, 6 pages for large proposals), click on 'Return to Recent Activity' at the top of the form. This will take you to a list of all your recent proposals. For each listed proposal you can view your submission (the 'View' button), modify your submission (the 'Modify' button), delete your proposal (the 'Discard' button), or attach a file (the 'Files' button). The 'Files' button will take you to a 'Files Manager' webpage from which you can upload the PDF file with your scientific justification, or modify a PDF file you have already uploaded.

The scientific justification should be a single PDF file. The PI's Vita is not required. The font shall be no smaller than 10 pt, and need not include section headings. This text should include:

- The scientific description of your research plan.
- A short statement demonstrating the relevance of the proposed research to NASA's objectives (see Table 1 of the ROSES Summary of Solicitation (http://nspires.nasaprs.com/external/viewrepositorydocument/77809/Summary_of_Solicitation.pdf).
- A management section that describes the resources required, including the expected contribution of the different investigators. This section should provide an estimate of the level of effort (e.g., 0.5 FTE of a postdoc), but **not** the maximum budget request. NASA policy does not allow the peer review panel to see your total budget request. If you are submitting a multi-year large proposal then describe qualitatively the level-of-effort profile.
- If you are proposing for NRAO or NOAO observing time, please include your observing plan. To ease the review and implementation of your observing plan, please include all the relevant information in one contiguous section. Note that you cannot apply for more than 200 hours or Target-of-Opportunity (TOO) radio observations through the NRAO joint proposal opportunity, or for TOO or survey program optical observations through the NOAO joint proposal opportunity, but must instead apply through the cooperative proposal opportunity of each program.
- If you are proposing for NASA-Provided High-End Computing Resources, please describe and justify your request (see section 1d of the ROSES Summary of solicitation (http://nspires.nasaprs.com/external/viewrepositorydocument/77809/Summary_of_Solicitation.pdf).

Remember to attach the scientific justification file to your proposal!!!

10.4.1 Request for NRAO Observing Time

By agreement with NRAO, proposers interested in making use of the NRAO Very Large Array (VLA), Very Long Baseline Array (VLBA) or Robert C. Byrd Green Bank Telescope (GBT) facilities as part of their GLAST science may submit a single proposal through the "Joint Proposal Opportunity."

If you wish to make use of this opportunity, you must select the NRAO joint proposal program on the RPS form. You must then provide basic information about the requested observations (e.g., the number of hours on the particular NRAO facility). This information will be used by the peer review process.

You should provide the following additional NRAO-related information as part of your scientific justification (please group this information into one contiguous section of the text):

- Indicate the choice of NRAO telescope(s) (VLA, VLBA or GBT);
- For the VLA, indicate the requested configuration(s). Because of the Expanded VLA construction project, the future schedule for moving antennas into the different VLA configurations is still uncertain, so the predictions of configuration dates given at http://www.vla.nrao.edu/genpub/configs/ should be regarded as tentative;
- Enter the total estimated observing time and the observing wavelength(s) for each telescope/configuration; and
- Include in your scientific justification a full and comprehensive scientific and technical justification for the requested NRAO observing time.

Demonstration of the technical feasibility of the proposed NRAO observations is the responsibility of the proposer, and must include image sensitivity and fidelity needs. The technical feasibility based on the scientific justification text will be reviewed by NRAO before the proposal is evaluated by the GLAST GI program peer review. Detailed technical information concerning the VLA and the VLBA can be found at http://www.vla.nrao.edu/astro/ (VLA), at http://www.vlba.nrao.edu/astro/ (VLBA) and at http://www.gb.nrao.edu/gbt/ (GBT). In particular, note the comprehensive 'Observational Status Summary' for each telescope, posted at http://www.vla.nrao.edu/astro/guides/vlas/current/ (VLA), at http://www.vlba.nrao.edu/astro/obstatus/current/obssum.html (VLBA), and at http://www.gb.nrao.edu/astronomers.shtml (GBT).

If approved for NRAO time, successful PIs will be contacted by the VLA/VLBA/GBT Scheduling Officers (schedsoc@nrao.edu) once scheduling details are known. The successful PIs will then be responsible for submitting observing scripts to analysts@nrao.edu (VLA), to vlbiobs@nrao.edu (VLBA) or to the GBT. The deadline for the receipt of these scripts will be communicated by the VLA/VLBA/GBT Scheduling Officers. NRAO will perform final feasibility checks on these scripts and reserves the right to reject any observation determined to be infeasible for any reason. Such a rejection could jeopardize the success of the joint science program.

10.4.2 Request for NOAO Observing Time

By agreement with NOAO, proposers interested in making use of observing facilities available through NOAO as part of their GLAST science program may submit a single observing research proposal. The award of NOAO time will be made to highly ranked GLAST proposals and will be subject to approval by the NOAO Director. Note that proposals that require TOO observations or survey proposals (under the NOAO Survey Program) should propose through the NOAO proposal process and will be considered for GLAST GI program funding after successfully being awarded telescope time.

The available telescope time is:

- CTIO Blanco 4-m telescope (5%; approximately 15–18 nights a year; no queue mode)
- SOAR 4.2-m telescope (1.5%; this is 5% of the 30% share of time NOAO has on this telescope; no queue mode)
- KPNO Mayall 4-m telescope (5%; approximately 15–18 nights a year; no queue mode)
- WIYN 3.5-m telescope (2.0%; this is 5% of the 40% share of time NOAO has on this telescope; no queue mode)
- KPNO 2.1-m telescope (5%, with perhaps up to 15% depending on the collective proposal pressure for this telescope; approximately 15–50 nights a year; no queue mode)
- WIYN 0.9-m telescope (up to 5%, approximately 15-18 nights a year; via NOAO time on this telescope; note that this will generally not include the use of the MOSAIC-1 imager with this telescope, as very little time is available for NOAO users on the WIYN 0.9m using this instrument and requests for MOSAIC-1 on WIYN 0.9m via the GLAST GI program will be scheduled on a best effort basis; some queue modes)
- Gemini-North and Gemini South (5% of NOAO time, which is approximately 40 to 45% of the nights, exact number depending on engineering of the commissioning schedule; note that recommended programs will have to submit the NOAO proposal form to aid the NOAO TAC assign GLAST-recommended observations to priority bands in the Gemini queue program)
- HET (up to 5% of available NOAO time on this telescope; the amount varies but is generally only a few nights a year; queue mode)
- SMARTS (5% of NOAO time, or 60 hours/year, and <1 hour on any one night, on each of the four telescopes. See http://www.ctio.noao.edu/telescopes/smarts.html; some queue modes)

The primary criterion for the award of NOAO time is that NOAO data are required to meet the scientific objectives of the proposal. Both observing research proposals are eligible. NOAO observing time will be divided roughly equally between the first and second semesters covered by GLAST's Cycle 1.

Proposers wishing to make use of this opportunity must provide the following additional NOAO-related information as part of their GLAST science justification:

- Indicate the choice of NOAO telescope(s) and instrument(s) (dates of availability for the various telescopes and instruments can be found on the web at: http://www.noao.edu/gateway/nasa/ or through the regular NOAO Proposal pages linked off the NOAO home page, http://www.noao.edu/.

- Enter the total estimated observing time (hours) for each telescope/instrument combination; note that many telescopes award time in half-night or night increments

- Specify the number of nights for each semester during which time will be required and include any observing constraints (dates, moon phase, synchronous or synoptic observations, etc. For synchronous or coordinated observations confirmed details of the observations whose scheduling must be matched should be included at the time of submission of the program.)

- Include a full and comprehensive scientific and technical justification for the requested NOAO observing time; and

- Provide a plan for the public release of the NOAO data, if this is part of the proposed program.

Demonstration of the technical feasibility of the proposed NOAO observations is the responsibility of the proposer. Detailed technical information concerning NOAO facilities may be found at http://www.noao.edu/.

GLAST will transmit to NOAO the selected proposals within one month of completion of the peer review. Successful PIs will be contacted by NOAO once scheduling details are known. Some programs might end up not included in the NOAO schedule due to practical constraints (e.g., limited availability of needed instruments). If holding a program for scheduling in a following semester is possible this will be considered, but not guaranteed. Successful PIs (i.e., their programs have been scheduled) will be responsible for submitting observing preparation forms as detailed by NOAO.

If the GLAST GI program approves observing time on either of the Gemini telescopes, the PIs will be requested to submit the full NOAO proposal form in advance of the meeting of the Gemini TAC. This form will be used by the TAC to assign the GLAST-recommended observations and other approved Gemini programs to priority bands 1, 2 or 3, used for scheduling these telescopes and managing the Gemini Observing Queue.

10.4.3 NASA-Provided High-End Computing

NASA-Provided High-End Computing (HEC) resources can be requested through a proposal to the GLAST GI program. NASA provides these resources through computing clusters at GSFC and Ames Research Center; see https://www.hec.nasa.gov/. You should indicate that you are proposing for this joint program on the RPS form. Then in the scientific justification describe and justify the resources requested, including the processor hours and storage capacity required, and when during proposed period the resources will be required. For additional information about this program, please see §I(d) of the ROSES Summary of Solicitation.

10.5 RPS TOO Requests

TOO requests are also submitted through the RPS system. In Cycle 1 you can only request a new TOO observation, and cannot propose TOO observations through the GI program. Note that you must have an AKBAR account and be a member of the GLAST TOO proposal group ('GLAST Target of Opportunity RPS (GLASTTOO)') to submit a TOO observation request through RPS.

After logging into AKBAR, click on 'GLAST Target of Opportunity RPS (GLASTTOO).' This will lead you to a webpage from which you can submit a new proposal, or modify an existing proposal. Choose to submit a new proposal. Most of the fields are self-explanatory (and there is an accompanying help page that is accessed by clicking on the field title).

There are two choices for 'Urgency of Target of Opportunity.' 'Immediate' indicates that the observations should be made as soon as possible; the requirement is that the observation beginning within 6 hours after the Project Scientist approves the TOO request (but probably less time will elapse). 'Next business day' indicates that the request should be considered, and if approved implemented, during the next business day when the MOC and GSSC are both staffed.

You may save your draft TOO request to your computer (using the 'Save' button) before submission. Remember to actually submit the request (using the 'Submit' button)!

11 Abbreviations and Acronyms

AAS	American Astronomical Society
AKBAR	Astrophysics Knowledge Base for Analysis and Reporting
ARR	Autonomous Repoint Request
AURA	Associated Universities for Research in Astronomy
BATSE	Burst And Transient Source Experiment
CTIO	Cerro Tololo Inter-American Observatory
DEC	Declination
EGRET	Energetic Gamma-Ray Experiment Telescope
EUD	Exploration of the Universe Directorate
FITS	Flexible Image Transport System
FOT	Flight Operations Team
FOV	Field-of-View
GBM	GLAST Burst Monitor
GCN	Gamma-ray burst Coordinates Network
GI	Guest Investigator
GIOC	GBM IOC
GLAST	Gamma-ray Large Area Space Telescope
GRB	Gamma-Ray Burst
CGRO	*Compton Gamma-Ray Observatory*
GSFC	Goddard Space Flight Center
GSRD	Ground System Requirements Document
GSSC	GLAST Science Support Center
GUC	GLAST Users' Committee, now the GUG
GUG	GLAST Users' Group, formerly the GUC
HEASARC	High Energy Astrophysics Science Archive Research Center
HET	Hobby-Eberly Telescope
HQ	Headquarters
ICD	Interface Control Document
IDS	Interdisciplinary Scientist
IOC	Instrument Operations Center
IRF	Instrument Response Function
ISOC	LAT Instrument Science Operations Center
KPNO	Kitt Peak National Observatory
LAT	Large Area Telescope
MET	Mission Elapsed Time
MOC	Mission Operations Center
MMT	Multiple-Mirror Telescope
MSS	Mission System Specification
NASA	National Aeronautics and Space Administration
NOAO	National Optical Astronomy Observatory
NRA	NASA Research Announcement
NRAO	National Radio Astronomy Observatory
NSPIRES	NASA Solicitation and Proposal Integrated Review and Evaluation System
OGIP	Office of General Investigator Programs

PI	Principal Investigator
PMT	Photo-Multiplier Tube
RA	Right Ascension
ROSES	Research Opportunities in Space and Earth Sciences
RPS	Research Proposal System
SAA	South Atlantic Anomaly
SAE	Standard Analysis Environment
SMARTS	Small and Moderate Aperture Research Telescope System
SSR	Solid State Recorder
SWG	Science Working Group
TAC	Telescope Allocation Committee
TDRSS	Tracking and Data Relay Satellite System
TOO	Target of Opportunity
UTC	Universal Time Coordinated
WIYN	Wisconsin, Indiana, Yale and NOAO

12 Change Record

- June 7, 2007—First public release
- August 22, 2007—Major update before Cycle 1 deadline. Changes:
  - Launch date updated
  - GLAST-NOAO joint agreement incorporated
  - LAT performance updated
  - Change record added
- August 23, 2007—Only the first year budget number should be entered on the RPS form for multi-year large proposals.